SCHOOL OF CIVIL ENGINEERING

INDIANA DEPARTMENT OF HIGHWAYS

JOINT HIGHWAY RESEARCH PROJECT

JHRP-84-9

AN INVESTIGATION OF POTENTIAL ENERGY CONSERVATION FOR INDIANA DEPARTMENT OF HIGHWAY BUILDINGS

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PURDUE UNIVERSITY

Final Report

AN INVESTIGATION OF POTENTIAL ENERGY CONSERVATION

OPPORTUNITIES FOR INDIANA DEPARTMENT OF HIGHWAY BUILDINGS

To: H. L. Michael, Director
Joint Highway Research Project

May 1, 1984

Project: C-36-670

From: Donn E. Hancher, Research Engineer
Joint Highway Research Project

File: 9-11-15

The attached report is the Final Report on the JHRP Study "An Investigation of Potential Energy Conservation Opportunities for Indiana Department of Highway Buildings". The report has been authored and conducted by Gary Roderick Smith under the direction of Professor Donn E. Hancher.

Objectives of the research were to develop a series of recommendations of energy conservation opportunities that exist with respect to the building physical characteristics, to develop a similar series of recommendations for operations and maintenance of the buildings and to develop a comparison of actual energy consumption to the calculated consumption. All objectives of the research were attained and are detailed in the report.

The findings of the study have been reviewed with the IDOH Buildings and Grounds Division and we are continuing to work with them on implementation of the results.

Respectfully submitted,

Donn E Hancher

Donn E. Hancher
Research Engineer

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Final Report

AN INVESTIGATION OF POTENTIAL ENERGY CONSERVATION OPPORTUNITIES FOR INDIANA DEPARTMENT OF HIGHWAY BUILDINGS

by
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Project No.: C-36-670

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Prepared as Part of an Investigation

Conducted by

Joint Highway Research Project
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in cooperation with the

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West Lafayette, Indiana
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He would like to express his gratitude to his major professor, Dr. Donn E. Hancher, for his assistance and encouragement and professor Richard O. Walker for his guidance and comments.

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ABSTRACT

Smith, Gary Roderick. MSCE, Purdue University, May 1984, An Investigation of Potential Energy Conservation Opportunities for Indiana Department of Highway Buildings. Major Professor: Donn E. Hancher.

The Indiana Department of Highways owns a large and diverse group of buildings that have been acquired over the years through construction and purchase. The buildings date from the late 1920's to the present and are constructed of a wide variety of materials including: limestone, brick, sheet metal, and block. Many of these buildings have a substantial potential for conserving energy by requiring only moderate changes in the structure or revisions to the current operating and maintenance procedures.

The main focus of this study is on the examination of the vehicle maintenance buildings for potential conservation opportunities. The major emphasis is on changes to the physical characteristics of the structures. Operational and maintenance changes are also examined to the extent that they impact the energy consumption of the building. Proposed revisions to the structures are examined on the basis of cost effectiveness and are evaluated by the discounted payback period of the energy savings and initial costs of the revision. The study indicates that substantial sums of money can be saved through energy management techniques.

CHAPTER 1 INTRODUCTION

1.1 Statement of Purpose

The Indiana Department of Highways owns a large and diverse group of buildings that have been acquired over the years through construction and purchase. The buildings date from the late 1920s to the present and are constructed from a wide variety of materials including; limestone, brick, sheet metal, and block. Many of these buildings have a substantial potential for conserving energy by requiring only moderate changes in the structures or revisions to the current maintenance procedures. The main focus of this study will be on examining the vehicle maintenance buildings for their possible energy conservation opportunities.

The major emphasis will be on changes to the physical characteristics of the structures. Operational and maintenance changes will also be proposed to the extent that they impact energy consumption.

1.2 Objectives

In order to accomplish the primary goal of this study it was necessary to identify objectives that would have beneficial results for the Indiana Department of Highways.

Their benefits will be savings in terms of dollars currently being spent on energy purchases.

Energy conservation is a very broad topic that encompasses many diverse fields and technical specialties. Energy audits, solar design, lighting design, vehicle fleet maintenance and earth shelter design are a few examples of the areas identified with conservation of energy. The objectives for this study were restricted to energy conservation measures that were applicable to existing buildings. An example of a measure that would not be applicable in this study would be the investigation of the building orientation, since we are dealing with existing buildings and have no control over orientation. However, orientation is a prime example of an area that should be investigated for new structures scheduled for future construction.

The primary goal of examining existing buildings for energy saving potential was broken down into three objectives. The First Objective is to develop a series of recommendations of energy conservation opportunities that may exist with respect to the physical characteristics of the buildings. Physical characteristics are windows, walls, doors, roof and other areas of the structure that have a direct impact on the energy input needed to maintain the interior conditioned space. It is often possible to make changes to the physical characteristics of a building to improve the energy consumption pattern of the structure. The

improvements should be evaluated for their net economic impact in terms of their payback of the initial investment.

The Second Objective of the study is to develop a series of recommendations of energy conservation opportunities that exist with respect to operations and maintenance of the structure. An example of an operational problem would be security lighting that needs to turned on by personnel before leaving the building in the evening. This procedure requires the lights to burn throughout the early evening hours and continuously over the weekends. The installation of a photocell to control security lights is cost effective and partially removes security lighting from the day to day operations. The photocells and security lights will need periodic checks by maintenance for replacement and to ensure proper functioning.

The Third Objective will be to develop a comparison of calculated energy consumption estimates with actual billings for the structure examined. The comparison will serve several functions. First it will provide a check on the calculated consumption. Second the historical records will provide a data base from which the success of conservation measures can be compared and tracked after they have been implemented.

The recommended changes in the physical characteristics will be evaluated on the basis of a minimum four to five

year payback period. The short range of the payback period is to allow for additional revisions to the structures in a short period as new products or methods become available without discarding prior investment. All of the replacement materials selected for analysis will be presented in the calculations but do not represent the only materials available. In most cases several alternative materials would be equivalent in energy conservation quality but the pricing information obtained by the researchers may have excluded the product based on the current market price quotation.

1.3 Background

The last decade has shown a rapid change in both the use and control of all sources of energy. Figure 1.1 shows the projected energy consumption of the U.S. through 1990. The current forecast line indicates the expected change in consumption brought on by the oil embargo in the early 1970's.

Associated with this change is an increased awareness of individuals to the pressing problems associated with energy use and cost. Prior to the embargo of oil shipments in the early seventies there was little concern with the availability of energy resources. The pricing of energy resources never imposed a large problem for individual or business budgets. The oil embargo changed many of our expectations and focused national attention on our energy problems.

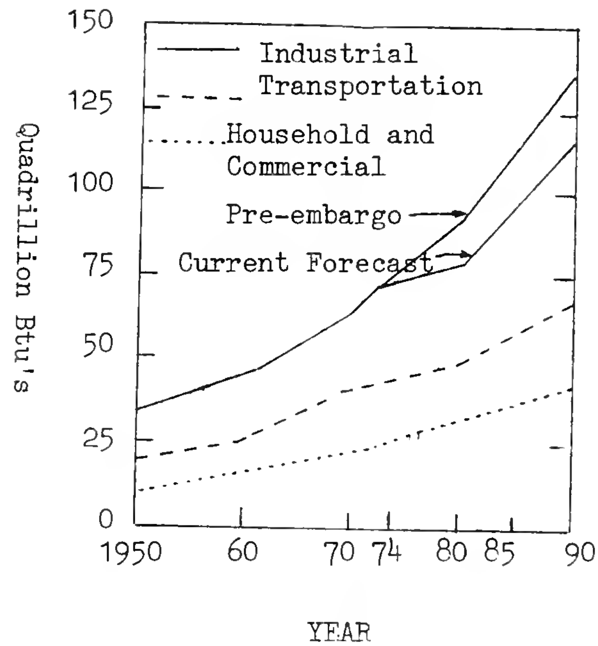


Figure 1.1 Forecasted Energy Consumption in the U.S. [10]

The Final Report of the Ford Foundation Energy Policy Project captured the underlying problem of the energy crisis. "The fundamental fact remains that the United States has entered a new age of energy, and we have not adjusted our habits, expectations and national policies to the new age."[3,25] This was a part of the problem in the initial energy crisis and remains as part of the continuing problem ten years after the embargo.

Much of our concern with energy is focused on prices, which have a direct relationship to the supply availability. A quick look at the price changes in the major components of

our energy sources shows the dramatic changes that have occurred in the retail prices of common fuels used in heating and transportation. The following list represents the approximate retail price of common fuels in early 1970s compared to current retail prices.

- Gasoline that cost around 35 cents per gallon is now $1.25 per gallon.

- Natural gas that was $1 per thousand cubic feet has risen to $6 per thousand.

- Heating oil was selling at 20 cents per gallon and now it is sold for $1.19.

- Electricity which sold for 1.5 cents per Kwh is now selling for 5 cents per Kwh.

The last three items on the list are the main components for most heating systems and for the foreseeable future they will remain the primary sources for heating and air conditioning energy. The four-fold increase in these costs is the reason that many organizations are taking a hard look at their facilities and trying to develop operational and maintenance programs to control the use of energy. The additional funds generated through energy conservation provide an additional source of plant operating capital.

Many steps have been taken in the recent past to either temporarily correct some of our national energy deficiencies

or to develop entirely new sources of energy and energy conserving products. Coal gasification, nuclear power, shale oil, geothermal energy, wind, solar and hydroelectric are all getting a close examination. In some instances of new technology, full scale pilot projects have been examined for feasibility. The latest trends for many of these developments are not encouraging. The high cost of nuclear power combined with other environment and political pressure has stalled, slowed or even stopped construction of many nuclear power generating stations. Shale oil and coal gasification are faced with many similar development problems. If it were not for price support guarantees, many of these new developments would not be economicly feasible. Solar energy and wind energy have had a lot of development over the last several years because the source is readily available and no predevelopment of the source is necessary; but, development of the technology to control and use the resources is slowly advancing. All of these new developments are primarily aimed at the long term energy problem and are not solutions for today.

Technology, environment, politics and international developments make energy sources a vital concern to everyone. The spiral of energy costs and development has had a very noticeable effect on the fixed budgets of public owners. Today, many public organizations are trying to reduce their budgets or at least maintain a static budget. This

situation requires that most owners concentrate on energy management and controlling the costs of heating and cooling by evaluation of their current structures.

The buildings that many organizations are currently using were built in the era of plentiful supply and relatively low energy prices. This is evident in the design techniques and main thrust of cost analysis during this period. Design related more to architectural appeal or to the minimum cost per square foot of structure. This is not to say that the designers and owners were intentionally creating a problem. Today, the impact of these previous design decisions is clear. Many previously functional and economical buildings are consuming a larger and larger share of owners' budgets. Although creative and cost effective designs have not been thrown aside, there is an increased use of techniques for analyzing the life cycle cost of a structure and more emphasis has been placed on reducing the initial energy consumption requirements of new structures. These changes are the result of increased public awareness and many independent efforts directed toward energy conservation and management.

There are three main systems in buildings that are directly related to the consumption of energy. Figure 1.2 graphically represents the interrelationships between these systems. The first system is the physical characteristics of the building. The window area, wall materials,

insulation, orientation, size, shape and color of surfaces can all have a direct impact on the amount energy required by the structure.

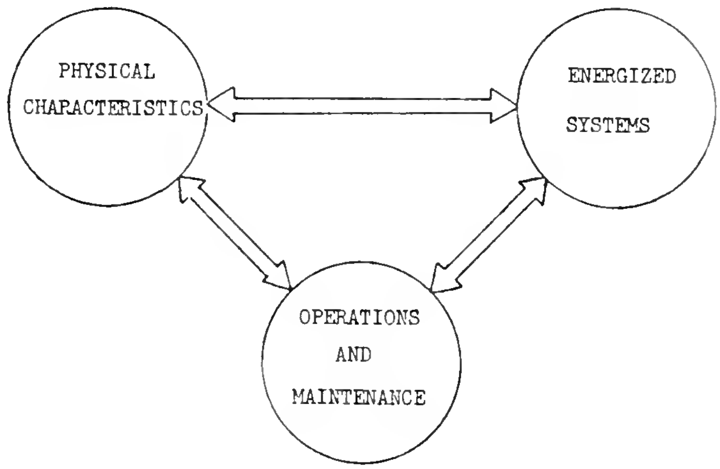


Figure 1.2 System Relationships

The second system is most commonly thought of regarding energy consumption. This system is referred to as the energized systems. Energized systems include the furnace, lighting, fans, and other equipment used in the building. The relationship of the energized system to consumption is the easiest of the systems to visualize and understand but often the poor performance of any component of the energized system is because of the poor use of the other systems.

The final system is operational aspects of the building. These are controlled by the occupants and their habits of energy use in the building. Operational systems include

such activities as hours of occupation, the number of times doors are opened and thermostat settings. These three systems within a structure are interactive. Each must be individually examined and related to the others in order to maximize the effectiveness of an energy management program.

1.4 Scope of Study

The Indiana State Highway is divided into six districts. The principal district used for this investigation was the Crawfordsville District in the west central section of Indiana. Before analysis of the buildings started it was necessary to classify the structures into identifiable types. A field investigation of the Crawfordsville District was the initial task completed for the study. Photographs of each structure were taken to facilitate the other districts in identifying similar structures in their districts and to ensure that uniform identification of all structures was possible. The key elements of identification and classification were as follows:

- Structure Type
- Age of the Structure
- Exterior Envelope
- Use of the Structure

The Crawfordsville District formed the basis for developing

a format for a survey request to the remaining districts. Table 1.1 represents the tabulation of structures by groups that was provided by the Crawfordsville District.

A copy of the survey information request to the Districts is included in Appendix A. Photographs of the various structures are also included in Appendix A.

The survey of the districts was completed with excellent cooperation from the districts during this phase of the project. More information was received during this phase than anticipated. Responses from the Districts included lists of some of the conservation techniques they have tried in the past and requests for individual attention on specific "problematic energy consuming" buildings. These specific requests on special problems were not addressed in the study.

The completed survey allowed the researchers to select target structures for study and analysis. Table 1.2 is the Building Classification Summary developed from the survey. The structures are separated by both District and Building Type. A total of 168 buildings are included in the table. The primary focus of this study is on the first five typical buildings. The structures selected do not necessarily represent the largest structures in terms of size or total heat losses. The Type I Building was specifically requested by Indiana Department of Highways on the basis that the

Table 1.1 Crawfordsville Building Summary

	STRUCTURE TYPE	EXISTING NUMBER
1.	New Block Design	5
2.	Arched Roof Block Design	5
3.	Metal Building	6
4.	Brick and Block Design	2
5.	Regular Block Design	2
6.	Wood Shed Design	1
	TOTAL	21

State is currently constructing a number of these buildings. The Type II Building was selected because it represented the largest population of any one type of structure in the State. The remaining structures were also selected by their population proportion. The Type VI Buildings were not included in the study. A brief discussion of Type VI is included with the study findings. The remaining structures on the summary table are either unique in design or did not represent a high enough proportion of the total group to warrant investigation at this time. The large number of structures involved in the study made it necessary to select a single structure in each category for analysis. The buildings selected to be studied are all located in the Crawfordsville District.

Table 1.2 Building Classification Summary

INDIANA DEPARTMENT OF HIGHWAYS DISTRICT							
Building Type	Crawfordsville	Greenfield	Fort Wayne	Laporte	Seymore	Vincennes	Total
I	5	3	1	3	4	3	19
II	4	7	8	12	11	11	53
III	3	1	0	4	1	2	14
IV	3	2	2	1	2	1	11
V	5	6	4	4	5	6	30
VI	2	1	0	2	1	6	12
Other Buildings	XII (2)	VII (2) X (1) XII (1) XV (1) XIX (3)	XII (1) XVI (1) XVII (2) IX (1)	XIV (1) XV (1) XVI (2) XIX (2)	XII (1) XIII (1)	VII (2) VIII (3) X (3) XI (2) XVIII (1)	32
TOTAL	24	28	20	32	26	38	168

CHAPTER 2 ENERGY MANAGEMENT

2.1 Introduction

The topic of energy conservation often creates an aura of a high technology discussion of thermal transfer and heat flows. The basic understanding of the physics involved is helpful but for the purpose of this study, perhaps, energy conservation is too general of a title and could be more easily understood as energy management.

Energy management is simply stated as a method that allows building owners to conserve both money and energy concurrently. The distinction between conservation and management is the effective use of a management system that will conserve energy but conservation alone may not be cost effective. Energy management is a method of cost effective conservation. The following section will outline the typical energy management system and the appropriate areas that are needed for implementation within the Indiana Department of Highways will be included in the discussion in Chapter 4.

2.2 Energy Management

The energy management system that is typically proposed can be outlined in five basic steps.

The energy management process starts with the commitment of top management. The daily working responsibilities of the system can be delegated to other groups within the organization. The need for top management support is essential to give the other groups within the organization the needed pressure to get involved and stay involved. Once the other groups are involved, the process needs to develop a "team spirit" feeling and everyone must understand that the system will break down if cooperation and continued awareness is not maintained. After management has given the commitment necessary, the next requirement is to select the committee to establish policies for the program and determine the teams that will be responsible for the execution of the program.

The first objective for the teams will be to obtain comprehensive energy use information on each structure to get a comprehensive view of the total energy use pattern for all structures and the interrelationship of the energy consuming systems for each structure. The use patterns can be developed through an audit of each building and calculation of energy consumption. The calculated usage should be compared to the actual billings obtained from utility companies. The comparison will determine if the calculated values are reasonable and what primary sources are most heavily used. This is the most time consuming portion of the program and reinforcement of the need for the program

may be necessary in this phase. The efforts required for this phase can be thought of as an investment that will have a beneficial payback when the system begins to operate.

The third step of the program should be to define the goals of the program in terms of measurable and realistic goals. The program should define some initial goals that can be determined by ranking the conservation measures developed in the energy use survey. The initial goals of the program require knowledge of budget constraints and future plans that may affect the structure under consideration. The need for a realistic level of improvement can not be stressed enough. If the goal is set too high, personnel may tend to ignore the program. A difficult goal will frustrate the implementation and as it becomes obvious that the goal can not be reached, personnel may decide that the entire program is unattainable and not worth pursuing. If the goal is set too low the potential for the program will not be developed soon enough. A realistic goal might be to achieve a 10 percent savings in energy consumption in the first year.

The fourth step is to subdivide general goals into subgroups or subprograms. Maintenance, renovation, new construction, and education are the most frequently referenced areas. The maintenance program is often the easiest to attack and develop systematic procedures. Checklists and occasional building examination by personnel are generally the suggested techniques. Maintenance is an important area

for ensuring that the program developed continues to be effective. Renovation and new building construction require more emphasis and input from budget constraints and feasibility studies. Education of employees is probably one area that gets ignored most often but it is an integral part of the package. Employees and the public need to be reminded that their cooperation and participation in the program is one of the key ingredients to a successful management program.

The final step in this system is to develop a method to evaluate the the on-going program. This will require the management teams to evaluate the total program progress. The activities for each subgroup can be evaluated in terms of their effectiveness well as their stage of development and implementation. Adjustment of activities and objectives may be necessary to realize the overall goals of the program.

Membership of the committee that will set the management program in action will need to have persons that have the necessary leadership and expertise to set policies that can be implemented. It should again be noted that the committee is a policy group and not the operations group.

The management teams should include people with the technical and management skills necessary to insure the program is being acted on and that the selection of procedures

or modifications are properly made. The most efficient manner of accomplishing modifications would be to time the the energy modifications with the upgrading of the current work area. If the final result of a modification is only a more modern working area that is no more energy efficient than the original layout, the program goals will not be met and may eventually lead to a complete failure of the program.

The obvious problem with the teams responsible for doing the energy surveys and development of recommendations is finding sufficient personnel with the technical skills to perform calculations and analysis of information. The basic skills and knowledge can be learned fairly easily, but most important is that the teams be able to contact or consult experts in specialty fields for complex situations or for recommendations on difficult problems. With this in mind a possible step in the development of the energy management program would be to train personnel through formal education and hands-on evaluation of some less complex buildings.

2.3 Energy Audits

An energy audit is the key to the energy management program. The level of detail obtained through an audit will be determined by the current level of knowledge of the individual performing the audit and the current status of the management program. The purpose of an audit is to examine the building under consideration for energy conservation

improvements. The building is examined for determining the relationships of the three building systems identified earlier. These systems were the physical characteristics, energized systems and the operational characteristics.

2.3.1 Building Information Form

The primary tool for the field audit is the Building Information Form (BIF). The form adopted for use in this survey was obtained from the Indiana Department of Commerce Division of Energy Policy and modified earlier by Indiana Department of Highway personnel for IDOH use. The basic format was retained and the form was modified to allow more information to be added depending on the circumstances.

The main sections of the building information form are presented for examination in Figure 2.1 on pages 20 through 25. The objective here is to explain the different sections of the form and how they fit into the various processes required to analyze a particular structure. The complete form is included in Appendix B for reference.

Section I is the general information section that is primarily used to identify a particular structure. This section also has the area to define the operational hours and basic building type and materials. The operational hour information is important for lighting calculations and determining the heat load if the building uses a setback thermostat. Description of the building materials is a

BUILDING INFORMATION FORM (BIF)

I. General Description

A) General:

Name of Building ______________________

Location ______________________

City ______________ Telephone Number ______________

Contact Person ______________ Position ______________

Use: ______________ Sub-District ______________

District ______________

B) Building Type:

Metal ______________ New Block Design ______________

Brick & Block ______________ Arch-Roof ______________

Combination ______________

C) Operating Schedule:

	time	hours	operating temperature	Number of occupants
Day	___	___	___	___
Evening	___	___	___	___
Night	___	___	___	___
Weekends	___	___	___	___
	___	___	___	___

II. - Building Characteristics

Year of construction ______________.

Year(s) of Modifications ______________.

Figure 2.1 Building Information Form

A) Floors

Construction (1) over heated space ______sq.ft.
over unheated space ______sq.ft.
slab on grade ______sq.ft.

(2) concrete ______sq.ft.
other (specify)____________________ ______sq.ft.

(3) Perimeter Insulation
type__________thickness__________(in)R-value__________

B) Walls

1) NORTH

a) Wall Construction

Gross Area length ______x height______ = ______ (sq.ft.)
Net Area (gross area-window and door area)

G.A.______ - W.A.______ = ______ sq.ft.

Outside
Construction: Metal Frame ______sq.ft.
Concrete Block ______sq.ft.
Brick veneer ______sq.ft.
Metal wall ______sq.ft.
Other (specify)__________________ ______sq.ft.

Insulation:

type __________thickness__________(in.)R Value__________

Inside
Construction: Block ______ sq.ft.
Wood ______ sq.ft.
Gypsum Board ______ sq.ft.
Metal ______ sq.ft.
Plaster ______ sq.ft.
Other (specify)__________________ ______ sq.ft.

Figure 2.1 continued

b) Window Construction

Single Glazed		______ sq.ft.
Double Glazed (space		______ sq.ft. ______ in.)
Insulating Glazed (space		______ sq.ft. ______ in.)
Other (specify)	______	______ sq.ft.
Shading (specify)	______	______ sq.ft.
Window Frame Type	______	
%sash/glass	______	%

c) Door Construction:

		No.	height	width	thickness
Wood	______	___	___	___	______
Metal	______	___	___	___	______
Glass	______	___	___	___	______
Overhead	______	___	___	___	______
Description	______				
Other(specify)	______	___	___	___	______

C) Roof

a) Roof Construction

1) Description of Frame ______________________________

____

______________________________.

Figure 2.1 continued

2) Roof Angle

Flat ________sq.ft.
Pitch ________sq.ft.
Arched ________sq.ft.

3) Roofing Material:

shingles ________sq.ft.
steel ________sq.ft.
built up ________sq.ft.

Other (specify ________________________ ________sq.ft.

Color Light __________Dark __________

Condition good ________fair________poor________

4) Insulation

type ______________thickness________(in) R-Value__________

5) Inside Cover Description ____

____

____

D) Ceiling Construction

1. Attic yes________ no________
Ventilation type ____
Use ____
2. Upper covering description ____________________________________
____
3. Frame description ____
____
4. Lower covering description ____________________________________
____
5. Insulation
type ____________thickness___________(in.) R-Value___________

E) Building Measurements

1. Heated
Total Floor Area
Length ______(ft) x width ______(ft) = Area ________(sq.ft.)

Figure 2.1 continued

2. Unheated

   Total Floor Area

   Length ________(ft) x width ________(ft) = Area __________(sq.ft.)

3. Number of stories __________

   Building height __________ (ft.)

4. Perimeter __________ (ft.)

III. MAJOR ENERGY USING SYSTEMS

Fill in the appropriate numbers for items 1 thru 5 using the numbered codes listed on the next page:

	Fuel Type(A)	Mechanical Equipment (B)	Terminal Unit(C)	Thermostat Setting-°F
1. Space Heating	______	__________	_______	_________
2. Space Cooling	______	__________	_______	_________
3. Hot Water	______	__________	_______	_________
4. Kitchen	______	__________	_______	_________

Kitchen equipment description ________________________________

____

Figure 2.1 continued

IV. AIR LEAKAGE (note quantity, location, etc.)

Cracks through walls or ceiling______________________________

Loose-fitting windows______________________________

Loose-fitting doors______________________________

Loose-fitting air conditioners______________________________

Ventilation exhaust ducts without dampers____________________

Others observed (described)______________________________

V. OPENING USAGE

A) Doors Persons/Hour ________________

B) Overhead Door Number of times/day________________

Avg. time open____________________(min)

c) Windows	N______	hrs/day______	Season______
	S______	______	______
	E______	______	______
	W______	______	______

VI. CLIMATIC DATA

Average Annual Heating Degree Days________________

Average Annual Cooling Degree Days________________

Main Wind Direction ________________

VII. DESCRIPTION OF ENERGY MANAGEMENT ACTIVITIES

Energy Management Team Formed Yes____ No____

Energy Management Coordinator Designated Yes____ No____

Energy Audit Completed____Started____ None____

Detailed Study by Architect or Engineer

Completed____Started____ None____

Energy Management Measures Implemented and Dates

____

____

____

____

____

____

____

____

Figure 2.1 continued

general classification and the detailed information can be presented in greater detail in the other sections of the form. Each structure is independent and will require a separate form. Often a structure has been modified or designed such that separate BIFs can be used for the modification, in the case of the addition of a new wing, or a separate form can be used for identifiable independent areas of existing structures. This method was implemented in the case of the Type IV Building where there were three separate types of construction used in a single building. Some of the information will be the same in the forms for the case where a building has been separated. It is convenient to fill in the major sections and identify where the separate sections are by means of a sketch.

The second section defines the building characteristics. The year of construction and modifications are asked for but are only informational in content. The modification information may be difficult to obtain and is not crucial to the completed form. The dates may provide some idea to the types of materials used in the modification. The remainder of the section is the heart of the physical characteristics system description. The subsections included are floors, walls, roof, ceiling and overall building measurements. The walls have been subdivided into the four cardinal directions to accommodate the building orientation. Only one wall direction is included in Figure 2.1 for examination, the

other sections are identical in content and would only be repetitious. Notes on the types of materials and construction in each of the areas will help in identifying location and possible measures for improving the energy requirements for a particular section. This information will be used in the calculation of the total energy losses relating to the physical design of the structure and for the determination of the possible alternative measures that can be used to reduce the building demand.

The third section is the information on the energized systems of the building including fuel type and types of equipment. The codes are included as a shorthand notation for the auditor. The lighting section requires identification of types, wattage and usage for both the interior and exterior lighting systems. The buildings that are zoned can be accommodated with this form by filling in the required information about the zones.

The fourth section is important because it identifies the major areas that are high infiltration areas. Cracks in or around windows, doors, ventilation ducts, air conditioners and other exterior wall penetrations should all be noted if the analysis and calculations are going to be meaningful.

The fifth section is related to opening usage of doors, overhead doors and clearly indicate if windows and doors are being used in a manner that is inefficient or costly in

terms of heating and cooling a building area. The reason that this information is of little value in the calculations is that the simplified formulas being used for analysis cannot account for doors opening. This is typically handled by system oversizing or by increasing the expected number of air changes per hour in the infiltration calculations.

The sixth section is the climatic data for the structure. Heating and cooling degree days and the main wind direction should all be available for the auditor to use in the building analysis. The heating and cooling degree data can be determined fairly well by information obtained from the National Weather Service. Although there is a large difference in data from one end of the State to the other it is not unreasonable to assume a constant within a district and establish all calculations for that district based on a single value.

The seventh and final section will enable the auditor to determine what, if any, activities have already been initiated in the building in relation to the program, and identify one person to be contacted for questions and periodic updating of the BIF for that particular building. In some instances energy conservation measures have already been implemented in the building. The auditor may be able to check the effectiveness of such measures and incorporate them in the suggested measures that should be taken to conserve additional energy.

Although several buildings may have the same general configuration and materials, a separate building information form should be filled out for each structure. The development of a generic form for multiple buildings can create the possibility that measures that would be effective in the building audited may not be effective in the others. The implementation of ineffective measures would be costly and would defeat the purpose of energy management. The importance of accuracy in reporting cannot be emphasized enough. The audit form by itself is meaningless if the information is not accurately reported. If items are left out or improperly recorded it will necessitate additional field investigation and possibly recalculation if the error is significant. The additional time and cost of these errors should be kept to a minimum. A complete building information form is included in Appendix B and the completed form for the Type I building is included with the calculations for the Type I building in Appendix C.

2.4 Computational Methods

The computations, as mentioned above, are not complex but a general review of the methods used in this study will facilitate the understanding of the entire process of energy management. This study required computation of five of the typical building types. The computations for the Type I building are included in Appendix C for reference. The remaining calculations were performed with a similar format

with only the conclusions based on the calculations presented in this report in Chapter 3.

2.4.1 Heating Load Calculations

The primary focus in this study was on the energy consumed through the heating systems. The cooling season calculations were prepared for some of the structures but no analysis was done regarding the results since many of the recommendations will reduce the cooling loads as well as the heating loads. The heating calculations can be broken down into six major components. The first requirement for the calculations is to obtain a set of drawings for the structure. Figure 2.2 is the example that will be used throughout this section to facilitate the explanation of the calculations. The actual drawings should be carefully reviewed and compared to the structure at the time of the field investigation. If drawings are not available a set should be developed from actual measurements of the building. A full review of the calculations would indicate the field measurements necessary to calculate the heating load of the building. In addition to the building the design conditions must be determined. The design conditions for the general location of the building can be found in most manuals for load calculations. The design temperature for the Lafayette area for winter time is 3 degrees Fahrenheit. The indoor design temperature selected was 70 degrees.

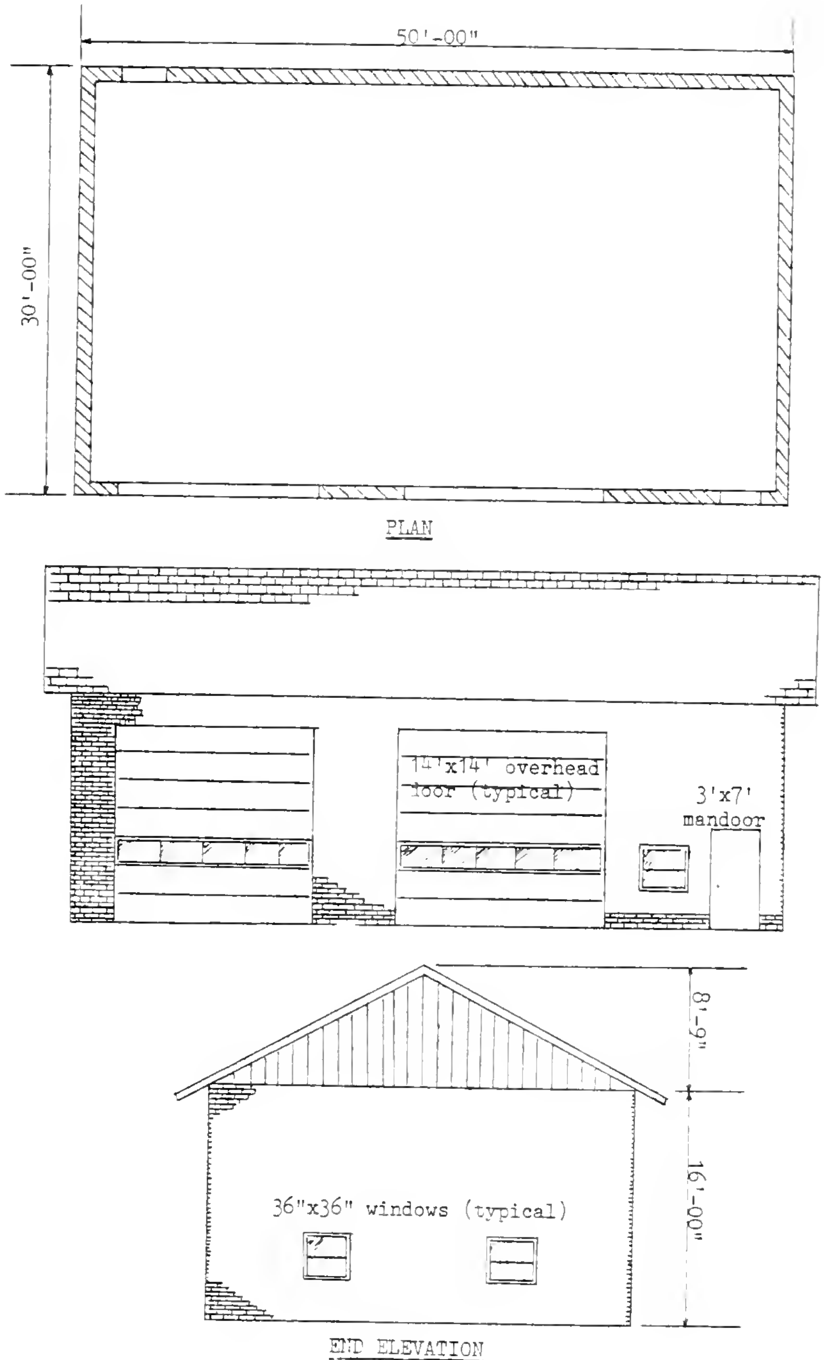


Figure 2.2 Sample Building

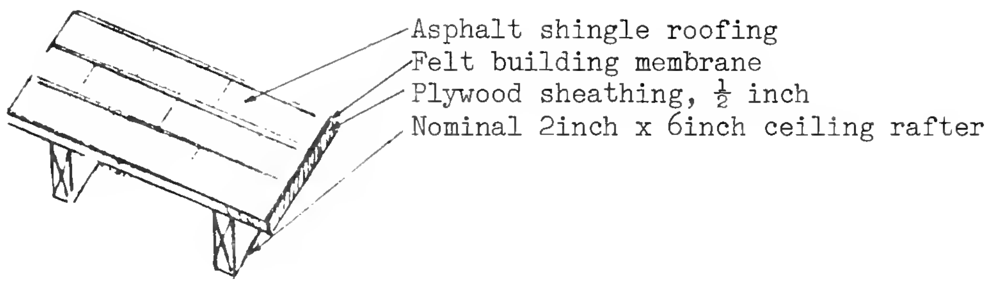


Figure 2.3-Typical Roof Section

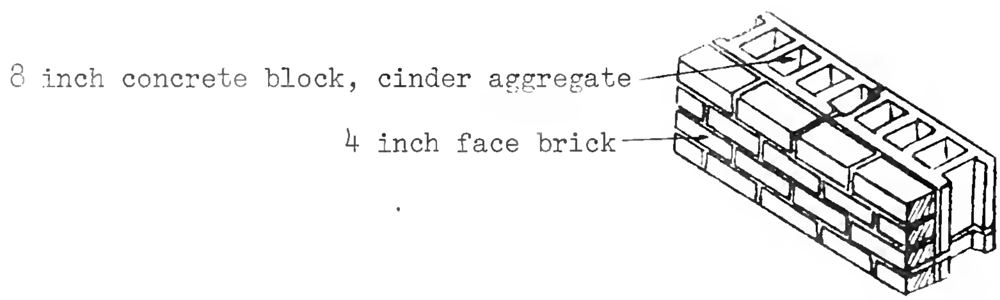


Figure 2.4-Typical Brick/Block Wall Section

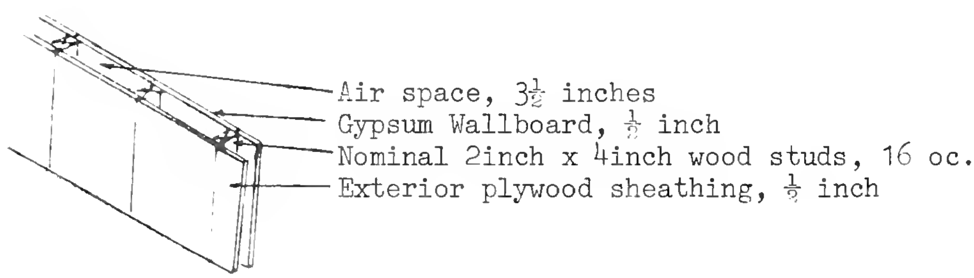


Figure 2.5-Typical Exterior Sheathing Section

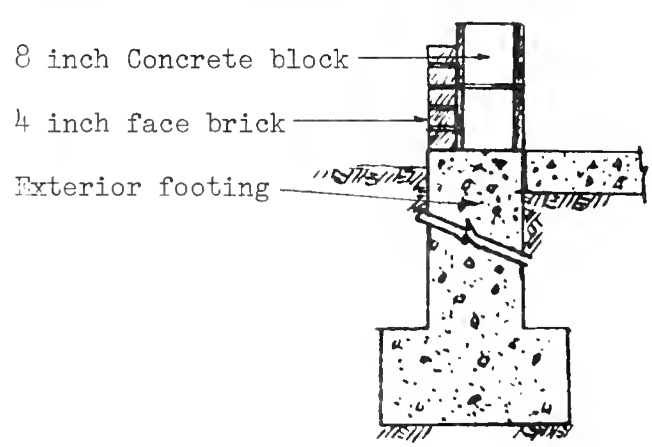


Figure 2.6-Typical Perimeter Wall Section

The second step is the calculation of the surface areas required for the various formulas. Typical areas required in the formulas are windows, doors, walls, ceilings, roof and floors. Referring to the example in Figure 2.2 the following areas can be determined.

The roof area is calculated based on the net area that will transmit heat to the outside. The eaves in this this example are an area that will not have heat loss. The slope length of one half of the roof can be calculated as 17.4 feet. The calculation of the roof area is as follows:

ROOF AREA = 2(17.4)(50) = 1740 square feet.

The wall areas are best calculated based on their orientation. In the example problem the gross wall areas are calculated as follows:

NORTH WALL (GROSS) = (50)(16) = 800 square feet.

EAST WALL (GROSS) = 1) Brick = 30(16) = 480 square feet

2) Siding = 30(8.75)/2 = 131 square feet

SOUTH WALL (GROSS) = 800 square feet.

WEST WALL (GROSS) = 1) Brick = 480 square feet.

2) Siding = 131 square feet.

The formulas do not use the gross wall areas. The doors and windows must be deducted to obtain the net wall area.

DOORS

NORTH WALL = 3(7) = 21 square feet

SOUTH WALL = 3(7) + 2(14)(14) = 413 square feet.

WINDOWS

SOUTH = 3(3) = 9 square feet.

EAST = 2(3)(3) = 18 square feet.

WEST = 18 square feet.

The remaining step in determining the net wall areas is to deduct the window and door areas from the gross wall areas.

NET WALL AREAS

NORTH = 800 - 21 = 779 square feet.

EAST = Brick = 480 - 18 = 462 square feet.

Siding = 131 square feet.

SOUTH = 800 - 413 - 9 = 378 square feet.

WEST = Brick = 462 square feet

Siding = 131 square feet.

The third step is to determine the coefficient of thermal resistance(R) for the materials used in the various elements of the structure. The inverse of R is the U value or the coefficient of transmission. The U value is used in the formulas for determining heat flows. The coefficients that are used here are from the ASHRAE Heating and Cooling Load Calculation Manual.[2,3.4-3.7] Thermal properties that are useful for determining the heat load of a building are thermal conductivity (k) and conductance (C). From these two units the resistance (R) of a material can be determined.

The conductivity value is based on a per inch of thickness and the conductance values are based on a fixed value of thickness. In either case the resistance value (R) is 1/k or 1/C depending on the application. The inside and outside air surfaces also have some thermal resistance properties and are accounted for in the calculation of the total resistance. In framed buildings the resistance value for two areas must typically be determined. The resistance at a wall stud is not the same as the resistance between the studs and these differences must be accounted for in the total value for the surface.

The first section that will be examined is the roof. A typical section of the roof can be found in Figure 2.3. The coefficient of transmission (U) for the roof is determined as follows.

CONSTRUCTION	RESISTANCE	
	AT RAFTER	BETWEEN
1. Outside air Surface	0.17	0.17
2. Asphalt Shingle	0.44	0.44
3. Felt Building Membrane	0.06	0.06
4. Nominal 2" X 6" Rafter	4.40	----
5. 3/4" Plywood Sheathing	0.93	0.93
6. Inside Surface Air	0.62	0.62
	------	------
TOTAL RESISTANCE (R)=	6.62	2.22
U = 1/R	0.151	0.450

The average U value for the roof can be determined by a weighted average of the two sections. In typical 16 inch center construction the rafters will cover approximately 10% of the total surface area.

$$U\ Roof = .10(.151) + .90(.450) = 0.420$$

The units associated with the U value are Btu per hour per square foot per degree Fahrenheit difference between the two surfaces. The outside air surface figures are based on a 15 mile per hour wind.

Similar calculations for the wall areas shown in Figures 2.4 and 2.5 result in the following values.

- Brick/Block Walls U= 0.332

- Exterior Sheathing U= 0.302

The values that are left to determine are the man door, overhead door and window U values. The doors can be determined in a manner similar to the calculations for the walls and roof. For the purpose of this example the man door U value will be 0.46 based on Table 3.6 [2,3.14] for a 1-3/4" solid wood core door. The overhead doors are 0.167. This value is based on the overhead door from the Type I building The window U value is obtained from Table 3.14A. [2,3.24] The assumptions for this example are that the windows have no shade and are thermal pane with a 1/2" air space between glass surfaces. The resulting U value from the table is 0.49 Btu/hr-sf-dF.

The heat loss from the building perimeter must also be determined. The typical perimeter section is shown in Figure 2.6. The section of the perimeter wall indicates a 6 inch slab on grade with no perimeter insulation. Instead of figuring a U value for the perimeter a direct heat loss based on a per linear foot basis can be approximated from Table 7.9A [2,7.22]. The estimated perimeter loss for this building example would be around 55 Btu/lf.

The crack method was used for determining the infiltration volume for the calculations. The standard procedure for using the crack method requires estimation of the lineal feet of cracks and open joints in the structure. A value is also determined for the opaque areas that is a function of the type of construction and how well the exterior is sealed. This is often determined at the time of the field investigation and areas that are obvious infiltration problems should be noted on the building information form. Calculation of the infiltration for the south wall is as follows.

Overhead door perimeter = 2(14+14)(2) = 112 Lf.

K = 3.0 [2,5.7,Table 5.8]

Gaps = 10(14)(2 doors) = 280 Lf.

K = 1.0 [2,5.7,Table 5.7]

Man Door Perimeter = 20 Lf.

K = 1.5 [2,5.7,Table 5.7]

Walls Area = 378 square feet

$K = 0.22$

(Assuming no stack effect or pressurization)

$dP = dPw$

$dPw = .000482\ Vw2\ Cp$

$Vw = 15$ miles per hour

$Cp = 0.95$ (pressure coefficient of windward side)

$dPw = (0.000482)(225)(0.95) = 0.1030275$

Q(volume of air) $= K\ (P)\ (dPw)^n$
$n = 0.65$ for leakage openings

The cumulative infiltration based on the above data is 167 cubic feet per minute.

The heat load for each area of the building is then calculated based on the design conditions desired and the physical properties calculated above. The two formulas involved for calculating the heat load are:

$Q = U \times A \times dt$ (for physical areas)

$Q = 1.08 \times (CFM) \times dt$ (for infiltration)

The peak heat load required can then be calculated by compiling the heat loads for the various areas of the building. The tabulation of the heat load and formula for annual heat load for the sample building is in Table 2.1.

The peak heat load is used to determine the total annual heating requirement and total fuel use. The natural extension to this calculation is the computation of the total cost of the yearly heating requirement. Based on the modified degree day formula above the total annual fuel use

Table 2.1 - Peak Heat Load Summary Table for Figure 2.2

LOCATION	AREA	U-VALUE	dt	HEAT LOSS (Q)
Roof	1740	0.420	67	48,964
Walls				
North	779	0.332	67	17,328
East(brick)	462	0.332	67	10,277
(siding)	131	0.302	67	2,651
South	378	0.332	67	8,408
West(brick)	462	0.332	67	10,277
(siding)	131	0.302	67	2,651
Doors				
Man Doors	42	0.460	67	1,294
Overhead	392	0.167	67	4,386
Windows	45	0.490	67	1,477
Perimeter Loss = 160 x 55 =				8,800
Infiltration = 1.08 x 167 x 67 =				12,084
Total Peak Hourly Load				128,597 Btu/hr

Annual Heat Load = Hl x D x 24 x Cd x Cf / dt x n x V

Where Hl = Peak hourly heat load (Btu/hr)

D = Heating Degree Days for the Building Location.

Cd = Interim correction factor for heating effect degree days.

D = degree days for the building location

Cf = Interim part load correction factor for fueled systems.

dt = design temperature difference

n = rated full load efficiency factor.

V = Heating Value of the fuel used in the building.

and cost for building are 3,626 ccf and $2,175.8 respectively. The total heat load and cost serve as the base against which the comparison to the historical records can be made. The comparison will indicate how accurately the computations model the existing building. The calculations are based on average design conditions. This can be a major source of error in comparing the computations to the actual billings. The specific period of time being compared can

also have a great effect on the comparison. Yearly fluctuations in the total number of heating degree days can have a great change on the fuel consumption calculation.

2.4.2 Lighting Calculations

The lighting requirements of the type of buildings being investigated can generally be best served by one of two systems. Either a high intensity discharge (HID) or fluorescent system will provide the most cost efficient source of general lighting. One consideration to be recognized is that lighting quality for a productive work atmosphere must be maintained. The latest series of energy efficient fluorescent bulbs reduces the overall lighting level by a negligible amount. These bulbs will reduce power consumption by around 15 percent in most cases where a compatible exchange bulb has been developed. The HID source that has gained some popularity has been the low pressure sodium bulb. It is a very efficient light source but has one drawback. The sodium bulb is a monochromatic light source. There are no percievable colors under sodium lights with the exception of yellow. This may limit any application of the sodium HID systems to the study. These background statements provide the justification for primarily analyzing what alternatives are available with the fluorescent lighting systems.

The example problem is calculated in Figure 2.7. The

GENERAL INFORMATION

Project identification: Sample Building (Figure 2.2)
(Give name of area and/or building and room number)

Average maintained illumination for design: ____ footcandles

Luminaire data:

Manufacturer: N/A

Catalog number: N/A

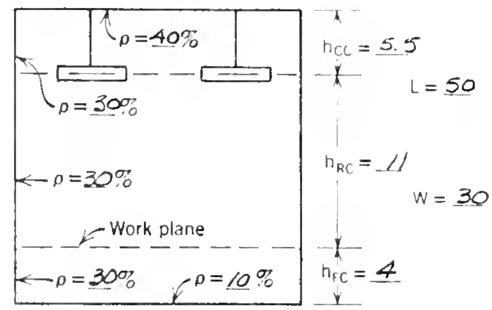
Lamp Data

Type and color: Fluorescent

Number per luminaire: 2

Total lumens per luminaire: 11600

SELECTION OF COEFFICIENT OF UTILIZATION



Step 1: Fill in sketch at right.

Step 2: Determine Cavity Ratios from Fig. 20.34, or by formulas.

Room Cavity Ratio, RCR $= 5(h_{RC})\left(\frac{L+W}{L \times W}\right) = 2.93$

Ceiling Cavity Ratio, CCR $= 5(h_{CC})\left(\frac{L+W}{L \times W}\right) = 1.07$

Floor Cavity Ratio, FCR $= 5(h_{FC})\left(\frac{L+W}{L \times W}\right) = 1.50$

Step 3: Obtain effective ceiling cavity reflectance (ρ_{CC}) from Table 20.9 — ρ_{CC} = 30 %

Step 4: Obtain effective floor cavity reflectance (ρ_{FC}) from Table 20.9 — ρ_{FC} = 9 %

Step 5: Obtain coefficient of utilization (CU) from manufacturer's data. — CU = 0.54

SELECTION OF LIGHT LOSS FACTORS

Unrecoverable		Recoverable	
Luminaire ambient temperature	1.0	Room surface dirt depreciation	0.85
Voltage to luminaire	1.0	Lamp lumen depreciation	0.85
Ballast factor	1.0	Lamp burnouts factor	0.95
Luminaire surface depreciation	0.9	Luminaire dirt depreciation LDD	0.87

Total light loss factor, LLF (product of individual factors above): 0.537

CALCULATIONS

(Average Maintained Illumination Level)

$$\text{Number of Luminaires} = \frac{(\text{Footcandles}) \times (\text{Area in square feet})}{(\text{Lumens per luminaire}) \times (\text{CU}) \times (\text{LLF})}$$

$$= \frac{40\ (1500)}{11{,}600\ )\ (\ .537)(.54)} = 18$$

$$\text{Footcandles} = \frac{(\text{Number of luminaires}) \times (\text{Lumens per luminaire}) \times (\text{CU}) \times (\text{LLF})}{(\text{Area in square feet})}$$

Figure 2.7 Zonal Cavity Method Example

Zonal Cavity Method is applicable for the general lighting conditions commonly found in garage applications. The evaluation of the reflectances of existing surfaces can be measured using a relatively inexpensive light meter. The lighting calculations yield the fixtures required as well as the footcandles per square foot. The lighting level will determine if there is adequate lighting being delivered to the work level. The number of fixtures required will also give a determination as to whether or not fixtures should be added or removed.

One particular section of the computations should be examined closer. The recoverable light loss factors are all maintenance related items. Maintenance factors are decimal values that are a maximum of 1.00 for any particular segment of the light loss factor calculation. The light loss factor is in the denominator of the equation. This indicates that the closer the overall light loss factor is to 1.00 the calculation for the number of fixtures will be minimized. The room surface dirt depreciation and the luminaire dirt depreciation are both related to frequency of maintenance cleaning. The higher the frequency for scheduled room surface and lamp surface cleaning the higher the maintenance factors. The lamp lumen depreciation and lamp burnout factor are both related to the replacement procedures. These are maximized by group replacement of all the lamps at predetermined intervals. Similar logic can be applied to the

coefficient of utilization. The lighter the colors are in a room, the higher the reflectances and the coefficient of utilization will be.

2.4.3 Value Analysis

The next phase of the analysis involves analyzing various proposals for reducing energy consumption on an economic basis. This phase analyzes alternatives that will require an initial cost to implement. The measures that require a change in maintenance or operation procedures can usually be considered as low or no cost alternatives and should be implemented without much hesitation. The Life Cycle Cost Analysis Form (LCCAF) in Figure 2.8 was developed for this study to aid in the examination of the alternatives proposed for reducing consumption. An example of an alternative will help to explain the form and the various steps for determining the payback period for the proposed alternative.

The alternative to be examined is the installation of a drop ceiling in the example building. The required data on the existing system is essentially the existing roof and the costs associated with the roof heat loss. No detailed calculations will be presented in this section. The methods for determining the values presented follow the procedures already presented earlier. The cost data has been assumed for this example. The following can be calculated for the existing system portion of the LCCAF.

POTENTIAL ENERGY CONSERVATION OPPORTUNITIES
LIFE CYCLE COST ANALYSIS FORM

Item Sample Building (Figure 2.2) Date

Description Comparison of Existing Roof System to Installing new Insulated Ceiling (Alternative No.1)

	Label	Item	Current System	Alternative No. 1	Alternative No. 2
Input Data	IC	Initial Costs ($)	--	$3500.00	
	FC	Fuel Consumption (units/yr)	1473 ccf	136 ccf	
	FP	Projected Average Fuel Price ($/unit)	$0.60	$0.60	
	AOC	Annual Operating Costs ($/yr.)	--	$30.00	
	EL	Estimated Life Time (yr.)	20	20	
Calculations	AFC	Annual Fuel Costs = FL x FP ($/yr.)	$883.70	$81.60	
	AFS	Annual Fuel Savings = AFC_C-AFC_A ($/yr.)	--	$802.10	
	AC	Annual Costs = AFC+AOC ($/yr.)	$883.10	$111.60	
	ACS	Annual Cost Saving = AC_C-AC_A ($/yr.)	--	$772.10	
	SPP	Simple Payback Period = IC/ACS (yr.)	--	4.5	
	PP	Payback Period* = n (IC=ACS (P/A, n, i%)) (yr.)	--	$7^{\pm}$	

* Assume an interest rate i = 12%
(P/A, n, i%) = Present Worth Factor

Figure 2.8 Life Cycle Cost Analysis Form

- Heat Loss Roof - 48,964 Btu/hr

- Annual Fuel Consumption - 1473 ccf

- Annual Fuel Cost - $883.70

The proposed system will be analyzed as if it replaces the roof as the exterior contact area. The calculations are performed in a manner similar to the methods already presented. If the new ceiling and insulation combination have an R = 22 the following data is estimated for the alternative.

- New heat loss - 4522 Btu/hr

- Annual Fuel Consumption - 136 ccf

- Annual Fuel Cost - $81.60

- Annual Operating Cost - $30.00

- Initial Cost - $3500

- Total Savings = $883.70 - 81.60 - 30.00 = $722.10

The example LCCAF has had the appropriate columns filled in based on this data and the two payback periods have been calculated to be 4.5 years for the simple payback period and approximately 7 years for the discounted cash flow payback.

2.5 Energy Data Base

An energy data base is a monthly compilation of energy consumption. The data base tracks the use of all sources of energy used in a building.

Two types of data are used in the development of a data base. The historical records of the building can normally be obtained from the utility companies that service the building or from the owner's records if the accounting system tracks both dollars and volume of use. The historical records aid the energy management system by providing an initial view of the energy consumption profile of the building. A review of the data may provide a clue as to the most important areas to be considered in reducing consumption. The historical records are also the base that will be used for comparison of the effectiveness of the improvements made to the structure. A less important use in terms of energy management but perhaps an important use for the owner would be to use the data to project annual budget requirements for energy expenditures.

The second type of data used in the data base is the current data. This data can be obtained from current billings or can be directly obtained by periodic observation of the utility meters. The periodic reading of the meters is perhaps the best method since the data is obtained quickly and if the measurements are timed correctly they can be used

as a check system for the utility company billings. The current data can be used to determine the effectiveness of energy management improvements made during the previous periods.

The energy management form is the key to the data base and an important element of the energy management program. Various forms are available to record the energy consumption. They can measure single energy sources or they can be cumulative for all forms of energy consumed by the building. Two general summary forms are provided in Figures 2.9 and 2.10. Both of these forms measure the total building requirements. Individual system forms are also available and are included in this study in Appendix D.

The form illustrated in Figure 2.9 has been adopted for use by the Indiana Department of Commerce, Division of Energy Policy in their publications [6,II-13]. This form is also illustrated in a handbook prepared by the National Electrical Contractors Association and the National Electrical Manufacturers Association in cooperation with the Federal Energy Administration (Now the U.S. Department of Energy).[12,8-9]] Although the form looks to be fairly complicated the mechanics required of completing the form are simple. The references noted above should be consulted for a complete explanation of the various types of data that can be used in the form. The main objective of this form is the development of the Energy Utilization Index (EUI). The EUI

Figure 2.9 Energy Management Form

_______________ Year

Month	Heating Deg. Days	Cooling Deg Days	Electricity						Purchased Steam						Fuel							Total Energy Cost
					kW Demand		Cost						Cost		Oil			Check Gas ☐ Coal ☐ Other ☐				
			kWh	kWh/ Deg. Days	Actual	Billed	Total	Per Ut.	M (lbs.)	M (lbs.)/ Deg Days	lbs/hr Actual	Demand Billed	Total	Per Unit	Quant (Gal)	Cost Total	Cost Per Unit	Quant	Cost Total	Cost Per Unit	Fuel/ Deg Days	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Jan																						
Feb																						
March																						
1st Quarter																						
April																						
May																						
June																						
2nd Quarter																						
July																						
Aug.																						
Sept.																						
3rd Quarter																						
Oct.																						
Nov.																						
Dec																						
4th Quarter																						
Total Per Year																						

Building Data

Gross Conditioned Area $(ft)^2$ _______________

Gen. Notes _______________

____

____

Annual Energy Consumption In Btu

	Quantity			Conversion Fac		Btu/Yr
1	________ Electricity	kWh	x	3413	=	________
2	________ Purchased Steam	(M) lbs	x	1,000,000	=	________
3	________ Natural Gas	MCF	x	1,030,000	=	________
4	________ Oil	Gallons	x	#2 138,700 #6 149,700	=	________
5	________ Other Fuel		x	________	=	________
				6 Total		________

Energy Utilization Index

$$EUI = \frac{\text{Total Energy Consumption Btu/yr}}{\text{Gross Conditioned Area }(ft)^2}$$

= _______________ $Btu/ft^2/Yr$

Figure 2.10 Energy Management Form

SUMMARY OF HISTORICAL ENERGY CONSUMPTION AND COST

BUILDING ____________

AUDIT PERIOD ____________

ALL ENERGY CONSUMPTION DATA ARE MILLIONS OF BTU

MONTH	ELECTRICITY		NATURAL GAS		FUEL OIL		OTHER		TOTAL	
	CONSUMPTION	COST (DOLLARS)	CONSUMPTION	COST (DOLLARS)	CONSUMPTION	COST (DOLLARS)	CONSUMPTION	COST (DOLLARS)	CONSUMPTION	COST (DOLLARS)
ANNUAL										

is an index value computed by dividing the total energy consumption of the building for the year by the gross building square feet. Without presenting all of the requisite calculations the EUI can be stated as a measure of energy consumption based on the square footage of the building. This provides a convenient basis from which to measure the energy consumption patterns of a building over a period of time. However, the EUI does not account for other factors that can affect the consumption pattern of a structure. Probably the largest influence that can change the EUI is the variation in heating and cooling degree days from period to period. In order to account for this difference the actual heating degree days can be tracked and the EUI adjusted accordingly. this will remove some of the environmental influences from the comparison of different periods. Other factors in the EUI that need to be either adjusted for or accounted for in some manner are: equipment changes, changes in working hours, additions or deletions of areas, and other similar factors that will have a measurable impact on the EUI.

The second form presented in Figure 2.10 is a simpler form that records only consumption and cost. This is adequate for most situations but does not give as much detail about the building requirements. The same general comparison can be developed from the form but more calculation is required outside the actual form itself. Which form is used will depend on the degree of sophistication of the

management program that is adopted.

The preceding sections have introduced the basic methods, computations and forms available for energy management and energy audits. There is a seemingly infinite amount of information available for all of the material presented and only the surface has been touched in this chapter to aid the novice in understanding the results of the study presented in Chapter 3. The References provided on pages 112 will provide additional sources of information for developing a better understanding of the requirements and a background of energy management and auditing.

CHAPTER 3 RESULTS OF THE STUDY

3.1 Introduction

This chapter is the presentation of the findings on the five typical building types examined for this study. The discussion of the findings on each building type are presented without the backup calculations. The calculations are somewhat repetitive in nature and only the calculations for the Type I building are included in this report. The Type I calculations are presented in Appendix C. The alternative measures discussed are not an all inclusive list of the possible improvements that could be implemented. They represent the measures that were considered to be the most practical and could possibly perform well enough to have a four year or less discounted pay back period. Often there are other constraints that will be noted regarding the particular building examined. The exact conclusions reached for these structures, presented may not be applicable for other similar structures and modifications to structures other than the ones audited in the study should be examined before implementation.

The study methods used will be discussed in terms of the actual steps taken prior to completion of the

calculations. The explanation follows the methods described in the previous chapter but are repeated here as a concise review of the procedure and as additional reinforcement to the necessary steps involved in energy management audits.

The analysis of a typical building starts out by selecting a specific building which is classified within that particular building type. The next step is to obtain the most recent plans available for the building. After a through review of the drawings, the building must be visited by the person conducting the audit. The site visit serves three purposes. First, it allows the auditor to note any remodeling that has been done to the structure and obtain necessary information about the remodeling. Second, the site visit allows first hand observation of the operational characteristics of the building. Last, it will allow the auditor to talk to personnel about their use of the building, complaints about energy related work conditions and to find out if they have any suggestions of their own to help in reducing their energy consumption. While the auditors are at the building it is suggested that the Building Information Form is filled in. Some items can be filled in at a later time but there are sections that should be filled in only at the time of the audit.

The estimate on the amount of energy consumed is based on the operational characteristics of the building and the physical characteristics, and is calculated in the manner

described in Chapter 2. Once the estimated energy consumption is complete the next step in the process is to examine the areas of the structure that consume the greatest amounts of energy. These areas are typically the source of greatest potential savings. Alternatives are generated for possible methods of reducing energy consumption in these areas. There are many sources from which these alternatives are generated including; field practitioners, various publications, past experience of the researchers and Indiana Department of Highway officials and employees. The alternatives require information from product manufacturers, estimated costs and estimated maintenance requirements for comparison and evaluation.

The evaluations of the alternatives are based on the amount of energy saved and the estimated pay back period for the installation. Two pay back periods have been calculated for each alternative. The first pay back period is the simple pay back period, which does not involve the time value of money. The discounted pay back represents the present value of the annual savings generated by the alternative to pay back the initial investment. The discounted pay back period is more realistic in terms of economic evaluation. Typically the alternative with the shortest pay back period will be selected. However, there will be instances where an alternative with a higher pay back period will be selected if the difference in the future savings warrants the

selection or if there are other considerations that need to be included.

It must again be pointed out that each of the buildings in a group are separate entities and each should be examined prior to implementing any suggested alternative. Often a spot check of the building questioned can provide enough information to decide if the alternative examined in this study will be applicable.

Some additional notes regarding the calculations and findings of this study should be reviewed to assure that the findings are interpreted properly. The study does not account for potential salvage value of any materials or equipment. The salvage values are often extremely judgemental and the net effect of salvage value would be a reduction in the time necessary to recover any initial investment. The fuel prices were current at the start of the study and may have fluctuated since the time the calculations were completed. An increase in fuel price will generate additional savings and thereby reduce the pay back periods calculated. The pay back periods for any alternative are not the magic number. There are numerous other factors that can influence the calculations. In addition to the fuel prices and salvage values, local economic conditions, proper maintenance, changes in operations, additional modifications to structures and changes in the interest rate used in the pay back calculation are a few of the other conditions that

can affect the evaluation of the structure. The effects of inflation were not accounted for in calculating costs. The interest rate used for determining the pay back period was fixed to be twelve percent. The reasons for fixing some of the numbers were that there are no reliable projections for fuel costs, and that if the increases in fuel costs are related to inflation then, in the future the total dollar savings will be larger than estimated, based on current dollars. These assumptions have simplified the calculations a great deal but the results are relative in terms of their economic impact to the owner.

3.2 Building Type I

The Type I Building is the new block building that is now being constructed in several locations. The basic exterior dimensions of the building are 62 feet by 46 feet. The calculations for this structure are provided in Appendix C of this study. Photographs of the Type I Building audited for this study are on the following page.

Table 3.1 is the comparison of the calculated U values for the main components covered by the ASHRAE Code for new building designs. The compliance column indicates that this particular style of construction does comply with the code and that there are not any substantial energy conservation opportunities with the physical characteristics of the building.

Figure 3.1 Building Type I

Table 3.1 Code Comparison Building Type I

SOURCE	CALCULATED U	MAXIMUM U	COMPLIANCE
CEILING	0.048	0.079	YES
WALLS	0.154	0.282	YES
FLOOR	0.10	0.219	YES

The heat loss calculations were performed to determine the maximum heat load conditions. The peak hourly heat loss was calculated to be 66,500 Btu/hr. The annual heating load estimated by the modified degree day formula was 131 million Btu.

The existing heating system in the building examined was an all electric system that has the capacity to supply the required heat to the garage area and the overhead employee area. The office, restrooms and storage areas have individual thermostat controls for electric baseboard heat. The main garage electric furnace was augmented in this structure by the addition of an overhead propane unit heater. The unit was not checked for efficiency and not addressed in calculations since this was a unique application and the analysis was restricted to features applicable to other identical structures planned for construction.

The study did address the application of other types of central heat plants for the garage area. The conclusion was

that natural gas heat would be the least expensive heat followed by fuel oil, electric, and propane. The costs for the systems based on local contractor estimated of material, labor and equipment necessary to install a new system or to change out the existing system. The pay back period for the natural gas alternative was approximately 3.4 years. One consideration for examining all prevalent heating systems was that the structures being examined will be built in various locations that do not always have access to the most economical utility.

Ceiling fans were examined for this particular structure. The calculations indicate that a possible 15 million Btu savings can be expected with the installation of ceiling fans. This represents approximately 11 percent of the total season heating load. Since the pay back periods are based on savings, the buildings utilizing the more expensive fuels will have a shorter pay back period. The maximum pay back period calculated was 3.2 years for natural gas heat and 1.7 years for propane heat. The four year pay back guideline indicates that this is a feasible alternative for this particular structure.

Several alternatives were examined for the lighting system. The first and easiest to examine was the relamping of the existing fixtures using new energy efficient fluorescent lamps. Relamping with F96PG17/LW/WM II lamps will cut energy consumption by 1709 kilowatt hours per year. The pay

back period for relamping is approximately 1.5 years. The other alternatives examined will require more cost and closer examination. Installing new energy efficient lamps and ballasts required more than twice the number of fixtures to maintain the current lighting level. This alternative required a 15 year pay back period for an existing building but does provide sufficient savings to warrant further investigation for future buildings planned for construction. The energy saved by this system over the current system, if installed in a new structure, results in a 3.7 year pay back. Another alternative is to install four 400 watt sodium lamps. This alternative does have an extremely good pay back in a new installation of 2 months based on initial cost differential. This alternative will require additional examination by a qualified lighting expert since the light coloration produced by these lamps may be unacceptable for the type of work being performed.

The following list represents some of the recommendations and comments regarding the operational conditions observed during the site investigation.

1. The fan on the furnace was operating continuously.

2. There were no exhaust hoses for the port hole outlets on the overhead doors. When an engine needs to operate during certain maintenance functions the overhead doors will be opened to vent exhaust gasses or the doors will

be opened and the vehicle moved outside. Either situation will result in a loss of substantial amounts of heat.

3. The windows are all wood frame and are in excellent condition. They should be checked frequently for caulking and weatherstripping.

4. The exterior flood light system was installed as a manual operation. This requires that personnel turn on the lights prior to leaving the building. This method of control requires approximately 6500 hours/year of operating time on the lighting system. The installation of photocontrols should reduce this time to an estimated 3650 hours/year. The pay back period for photocontrols will be less than one year and result in an annual savings of approximately $110 on electrical use.

Additional ideas for conserving energy for this particular building may be found in the general suggestions presented in section 3.7 of this chapter.

3.3 Building Type II

This building represents the largest single category of buildings in the State. There were 56 Type II Buildings identified in the survey and classification of existing buildings. The buildings are metal walls and roofs with a

nominal 2 inch insulation throughout. The building examined for the study was constructed around 1970 and has exterior dimensions of 63.5 feet by 30.0 feet. The building has on overhead door at each end and currently functions as a unit storage building.

The comparison of the U-values for this structure and other existing structures should be explained in more detail. The code values as determined by ASHRAE were designed as an aid for new structure design and not for implementation on existing buildings. They are useful in this study as a guide in identifying areas of the structures that could be deficient in insulation value. The application of the code is acceptable as a guide only since many of the modifications proposed, to improve efficiency, do not necessarily bring the existing structure within the compliance guidelines. The comparison for the Type II Building is shown in Table 3.2.

Table 3.2 Code Comparison Building Type II

SOURCE	CALCULATED U	MAXIMUM U	COMPLIANCE
CEILING	0.251	0.079	NO
WALLS	0.235	0.282	YES
FLOOR	5.57	0.219	NO

The walls are the only area that seem to be within the

Figure 3.2 Building Type II

compliance figure. The roof and floor are deficient and will require further examination for possible corrective measures. The alternatives for the roof system will be discussed below. Very little can be done with respect to the floor system at this time.

The peak hourly heat loss calculated for the building was calculated to be 100,110 Btu/hr. The modified degree day formula resulted in an annual energy consumption of 197 million Btu.

There were several alternative measures examined for the roof. The primary idea was to reduce the heat loss and also reduce the conditioned volume to the minimum acceptable height. The installation of a drop ceiling would serve to increase the insulation quantity and also reduce the volume that needed to have heated air. There were several alternatives examined for this proposal which are as follows:

1. Install a drop ceiling with 5/8 inch fiberglass panel.

2. Install a 3 inch fiberglass ceiling panel.

3. Install the 5/8 inch panel with an R-11 batt insulation.

4. Same as 3 above with an R-19 batt.

5. Same as 3 above with an R-30 batt.

The pay back periods indicated that the 5/8 inch panel with

either an R-11 or an R-19 batt would be the most acceptable. The pay back period associated with both alternatives was 5.8 years. This is beyond the four year targeted pay back period, and would yield an estimated annual savings of approximately $761.

The other alternative for improving the roof insulation would be to devise a method of directly attaching insulation to the underside of the roof. Discussions with several field personnel indicated that this had been tried with various adhesives and none have been found to be acceptable. The existing insulation has been suspended from a light gage wire mesh. This method of installation can be utilized here again to support the insulation if necessary. The pay back period associated with this alternative is 4.6 years and would result in an estimated annual savings of $761. The pay back period of this alternative is also beyond the 4 year target but it is closer to the target than the drop ceiling alternative.

A secondary problem is involved with either of the two proposed methods of treatment for the roof. The current lighting system is augmented by translucent ceiling panels. Covering these skylights will require the addition of lighting fixtures to the work area. This will be examined in the lighting calculations.

The walls were acceptable according to the code but

there are alternatives available that should be examined to possibly improve the wall heat losses as well. The alternatives examined for the walls were as follows:

1. Remove existing plywood install 6 inch fiberglass insulation and extend wall full height.

2. Same as 1 except using a 3 1/2 inch batt.

3. Extend plywood full height without adding insulation.

The computations resulted in none of the alternatives examined being acceptable within the 4 year target period.

The ceiling fan installation was also examined for potential savings on this type building. Two methods of installation were examined. The first was without the drop ceiling the second was with the drop ceiling. In either case the ceiling fans seem to save enough fuel to warrant their installation.

The two garage doors on the building investigated were in poor shape and very inefficient. Two manufacturers were contacted regarding costs for new insulated doors. The pay back period for the Raynor doors was estimated to be 5.6 years based on the discounted pay back. The pay back period calculated here is questionable due to the rough estimates obtained. However, the annual savings of $725 should be considered when all the alternatives are combined.

Lighting was the most difficult to calculate since it requires a complete new design if either of the two roof alternatives are accepted. The resulting calculations favored the alternative without the ceiling. There are no net savings that result from this alternative but an increase in initial cost and an increase in operating costs. The increase in the initial costs was roughly estimated to be $1560. The increase in the operating costs and maintenance costs for the lighting was estimated to be $352 per year.

The final step in the analysis of the Type II building involved the examination of the various combinations of improvements and modifications proposed above. Four basic alternative combinations examined were as follows:

1. Install ceiling fans and replace the overhead doors.

2. Install ceiling fans, cover the skylights, add lighting and replace the overhead garage doors.

3. Install ceiling fans, insulate the roof with R 19 insulation, replace the overhead garage doors and add lighting.

4. Install ceiling fans, add the suspended ceiling with R 19 insulation, add lighting and replace the overhead garage doors.

The alternatives are all outside the target range of four

years with the exception of only installing the ceiling fans. The primary factor involved in this analysis is that the savings involved in insulating the roof is more than offset by the projected need for interior lighting. The need for the interior lighting could be debated for this structure but that type of decision should be made by those who are more familiar with the use of the structure. A possibility that was not examined for cost effectiveness would be to keep the existing lighting level and add drop chord lighting for specific task areas within the building. In this scenario the cost of additional lighting would be minimal and alternate combination three would most likely yield the greatest net savings for the structure.

The following list of suggestions and comments are the result of the field observations of the Type II building.

1. The insulation existing in the building has several torn areas that should be mended or replaced.

2. The windows need to be caulked.

3. Some of the end seals for the exterior metal siding are missing or are about to fall out. They should be replaced or resealed.

4. There is a pipe placed through the exterior wall to permit hoses and other items to service the vehicles parked on the exterior. The pipe has no means of being sealed.

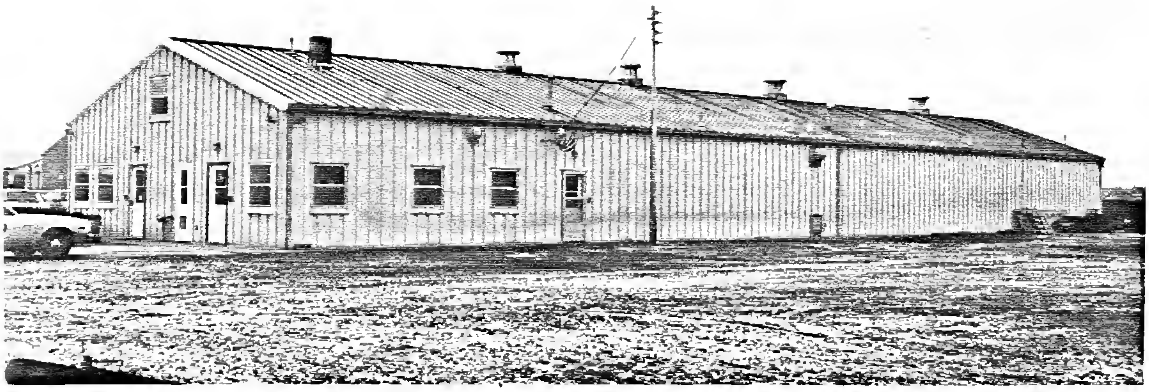
5. The existing man doors cannot be closed tightly and are in such a poor state that the should be replaced. This was not accounted for in the calculations noted above since this is a maintenance function.

6. There was no evidence of photostatic controls for the exterior security lighting. Controls are recommended.

The exact determination of which repairs and alternatives for these structures should be examined with regard for any phased plans being developed for their replacement. In the case that these buildings will be subject to replacement it could be possible to examine all the structures in the State and rank the replacements by the extent of repairs necessary to improve the overall efficiency of the structures.

3.4 Building Type III

The Type III Buiding is similar in construction to the Type II Building. It is an all metal building constructed around 1965. The major exception is there is only one overhead door. The dimensions of the Type III Building are 160.5 feet by 40.0 feet. This structure is divided into two primary areas. The office and overhead storage area and the connected shop areas. The two areas have been treated as independent zones with the primary focus on the shop and sign storage areas. The particular structure that was audited for this study has had considerable alterations and



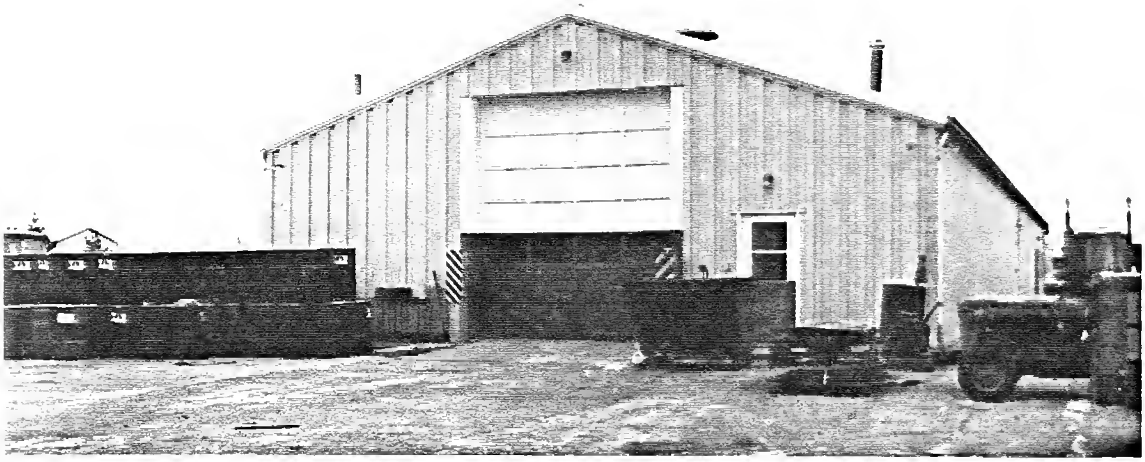


Figure 3.3 Building Type III

additions to the interior of the building. Offices that were added to the current sign storage area are essentially independent of the main building and are self contained with respect to energy consumption. The offices were constructed in a manner that would exceed the code requirements for insulation.

One of the largest consumers of electrical energy in this structure is the equipment for the sign shop. A manufacturer should be contacted to see if a more efficient model is available. The manufacturer data should be analyzed to see if it might be possible to reduce the overall cost of operation of the equipment and if the equipment change out would be economically feasible.

The heating load calculations estimated a peak hourly heat demand of 196,700 Btu/hr for the shop area and 24,500 Btu/hr for the office area. The annual heat loads were 339 million Btu and 48 million Btu respectively.

The comparison of the U values for this structure are in Table 3.3. The ceiling is the only area that does not comply with the new building design. The values presented in the table are weighted average figures that reflect the overall efficiency of the building and do not represent any one zone of the building.

Examination of the existing roof system indicated that there have not been any additions to the original design of

Table 3.3 Code Comparison Building Type III

SOURCE	CALCULATED U	MAXIMUM U	COMPLIANCE
ROOF	0.242	0.079	NO
WALLS	0.160	0.282	YES
FLOOR	0.042	0.219	YES

two inches of insulation. The skylights that could be covered with a section that will approximate the thermal resistance of the existing roof. Based on the estimated cost of the work and estimated heat savings resulting from covering the skylights, the net savings in heating would be $478 per year and the discounted pay back period would be around 8 years. The second alternative examined for the roof was to add 6 inches of insulation with the light gage wire mesh for support. The estimated heat savings from this alternate would be approximately $980. The discounted pay back period would be in excess of 25 years because of the estimated initial cost of $7150.

The current lighting system in this building would be sufficient if the decision would be made to cover the skylights. The only modification recommended for the lighting system is to eliminate some of the incandescent bulbs in a material storage room. The alternative examined for the overall lighting system is a change in the fluorescent

bulb type. The current bulbs require 75 watts per bulb. An energy efficient replacement for these requires only 60 watts per bulb. The pay back period is 3.9 years with the new bulbs and saves an estimated $242 per year. The final recommendation for the lighting system is to install photocontrols on the exterior security lights.

The Type III building does have fairly high ceilings that make excellent heat sources for ceiling fans. The current shop area would require two 52 inch fans. The fans will save an estimated $116 per year which results in a pay back period of approximately four years. The sign storage area would require one fan and will have a pay back of about 4.8 years based on a yearly savings of $50.

The wood overhead garage door in the sign shop could be replaced with a new energy efficient door with perimeter door seal. The replacement door would save an estimated savings of $280 per year. The pay back period for the door is 8.4 years which exceeds the target pay back of four years.

The site visits also revealed several other problems that should be corrected. Some of these may be corrected by the time this study is finished but they are noted here to indicate situations that are common to many structures.

1. One of the unit heaters had rusted through on one side and needs to be replaced as soon as possible. Another

had been recently replaced. The possibility that a corrosive atmosphere may exist since the two units are both in the sign shop area.

2. Not all of the thermostats had lock box covers. One thermostat was not working properly.

3. The electric hot water heater has a 52 gallon capacity. A smaller capacity hot water heater that is energy efficient could probably serve occupant needs and reduce the energy costs for hot water.

4. Broken glass in doors and windows should be replaced and caulked.

5. Storm windows should be checked for tightness and minor adjustments made.

6. If the overhead garage door is not necessary the possibility of removing it or replacing with a smaller door should be investigated.

The Type III building investigated for this study was in excellent shape and well maintained. This could explain why there were only a few comments that could be made with respect to energy savings. There are potential savings in the structure, but as the calculations show the pay back periods for the bulk of the potential savings exceed the targeted four year pay back period.

3.5 Building Type IV

The Type IV Buildings were constructed around 1965 and are combination office and maintenance buildings. The Type IV Building can best be described in three separate sections. The first section is the office area and is approximately 45 feet by 41 and an eave height of approximately 9 feet. The office section is constructed of face brick with a window wall section at the main entrance. The roof in this section is a concrete slab. The center section is the garage and repair area that has dimensions of 101.5 feet by 48 feet with an eave height of approximately 16 feet. The garage section is primarily constructed of uninsulated concrete block except at the two gable ends that project above the adjoining sections. The gable end projections are insulated metal siding. The center section roof is also constructed of insulated metal panels. The final section is 24 feet by 53 feet and has an eave height of 14 feet. The final section is the lavatory for the shop employees, storage and the original paint shop.

The paint shop in the building being audited was no longer in use and has been converted to material and parts storage.

The code comparison for the overall building is shown in Table 3.4. The table clearly shows that only the building walls are outside of the new design guidelines.

However, if the building is divided into the sections described above the center section is shown as not complying

Figure 3.4 Building Type IV

Table 3.4 Code Comparison Building Type IV

SOURCE	CALCULATED U	MAXIMUM U	COMPLIANCE
CEILING	0.085	0.079	NO
WALLS	0.520	0.282	NO
FLOOR	0.037	0.219	YES

in two areas. The ceiling and the walls in this section are outside the compliance recommendations. This comparison is shown in Table 3.5.

Table 3.5 Comparison by Area for Type IV Building

SOURCE	SECTION	CALCULATED U	MAXIMUM U	COMPLIANCE
CEILING	A	0.0571		YES
	B	0.1032	0.079	NO
	C	0.0648		YES
WALLS	A	0.383		NO
	B	0.552	0.282	NO
	C	0.541		NO
FLOOR	A	0.0284		YES
	B	0.0342	0.219	YES
	C	0.065		YES

The calculations for the heat loads were also separated according to the zones above. The office loads were determined to be 47,600 Btu/hr for the peak heat load and 94

million Btu for the annual heat requirement. The garage area peak heating load was estimated to be 276,300 Btu/hr which results in an annual heating load of 544 million Btu. The storage areas and lavatories required 78,400 Btu/hr and 154 million Btu annually. The primary areas that should be concentrated on based in the code comparison and the energy calculations would be the garage and storage areas.

Although the recommended values are based on the total building as shown in Table 3.4, it was helpful in this case to break the areas out to look for significant deviations. The breakdown indicates that the areas that should be carefully examined are the walls and ceiling of the center section and the walls in the end section. The analysis resulted in two alternatives for the center section. The first alternative was to insulate the ceiling to R-30 and the walls to R-19. The estimated savings generated from this alternative was $2470. The pay back period for insulating both ceiling and walls is approximately 7.9 years. The second alternative was to only insulate the walls and to do nothing to the ceiling. The estimated pay back period was 4.7 years based on savings of $1660. This is one of the cases where some other guideline, besides the lowest pay back period should be examined. The additional savings generated from the first alternative are significantly higher and would warrant the acceptance of the more expensive alternative.

Since windows are notoriously large consumers of building heat in winter months, the idea of blocking up the large window area in the garage was considered. The estimated cost for this alternative is very rough and may have an effect on the results of the calculations. The simple pay back period exceeded 12 years for both the alternatives considered in this scheme. The only solution that can be conceived under these circumstances would be to fabricate an insulated window insert that could be sealed to the openings during the winter months. Providing the insert can be sealed and insulates to approximately an R-20 the resulting savings should be around $460 per year.

The overhead doors for the Type IV building consume roughly 3690 ccf (hundred cubic feet) of natural gas between heat losses through the doors and the infiltration air volume. The replacement Raynor door for this structure with perimeter seal and fiberglass insulation should reduce consumption to about 965 ccf. The net savings of the new doors is approximately $1673 and has an estimated pay back period of 6.7 years. This is outside the target pay back period but still should be considered in light of the large potential that exists in the future.

The primary alternative examined for this structure with respect to lighting is the replacement of the existing bulbs to the new generation high efficiency bulbs compatible to the system. The savings generated can pay back initial

investment in slightly over four years. A lighting consultant should be contacted regarding the luminous panel lighting in the office area.

Ceiling fans were examined for application in the garage area and they again appear to be a feasible alternative in reducing energy consumption. The fans will save an estimated $380 per year enabling the initial costs to be defrayed in under two years.

Some additional comments on this particular structure are as follows:

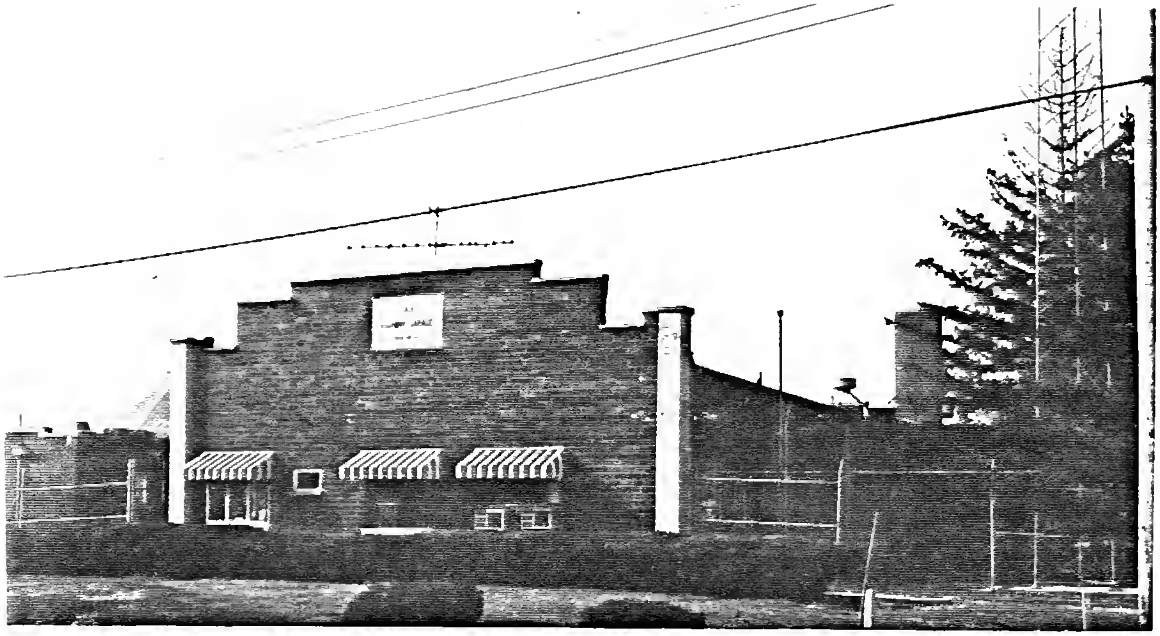
1. The thermostat in the former paint shop had to be set to 80 degrees to protect the telephone switching equipment installed in the room. This temperature is very high and perhaps consultation with the telephone service representative would result in a lower setting that could protect the equipment. This particular room also has an overhead door that appeared to be seldomly used. This door in combination with the equipment installed in this is an intolerable situation. The local personnel should make the decision about removing the door since they also utilize the room for storage. If the door cannot be removed and replaced with a smaller opening then the door should be sealed as much as possible to reduce heat loss and infiltration.

2. Exterior security lights should have photocontrols or a timer system installed.

3.6 Building Type V

The Type V Building is the final structure examined in this study. At the time the field investigation occurred the structure was being substantially modified with respect to roof insulation and lighting. The overall evaluation of the effectiveness of the insulation will be examined but the lighting installation was not complete and therefore it will only be addressed in general terms based on the site observations. The photographs of the Type V Building are on the following page.

Although the Type V Building is not unique in the overall total building count, there are some very unique features about the structure. The building is a barrel or arched roof composed of a wood deck on top of heavy steel trusses that span the entire width of the structure. When the structure was built around 1929 no insulation was placed in the roof and exterior walls. The first modification occurred around 1936 and included the addition of a boiler room and coal storage room along with the addition of a new work bay. The next modification that can be dated was in 1972 and involved the installation of a new heating system with a central air conditioning system for the offices. No additional records are available, but apparently sometime



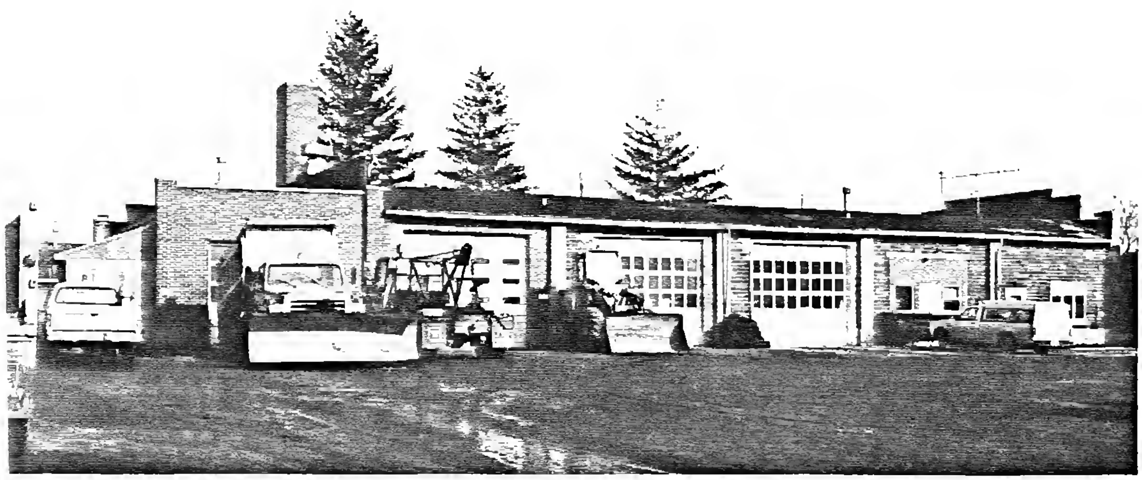


Figure 3.5 Building Type V

after the last heating system modification, an additional furnace was added to supply heat to the office area.

The duplicity of the office heating system presents a situation that should be examined closer by a qualified heating contractor. It would seem reasonable that a single system would be able to service such a small area with ease and higher efficiency. In addition, the central air unit is still connected and the office areas also have through wall air conditioning units.

The duplicity of systems in the office area is a good indication that there are problems both in heating and cooling the building. This is not very surprising if the code comparison is examined in Table 3.6. Neither the roof nor the walls are even close to compliance.

Table 3.6 Code Comparison Building Type V

SOURCE	CALCULATED U	MAXIMUM U	COMPLIANCE
CEILING	0.382	0.079	NO
WALLS	0.572	0.282	NO
FLOOR	0.053	0.219	YES

The calculations for heating load requirements were based on the structure as it was before the modification. The peak hourly load was determined for each of the sections. The office area required 58,100 Btu/hr. The bay area required

230,500 Btu/hr and the storage area required 88,000 Btu/hr. The annual loads for each area are 123 million Btu , 487 million Btu and 188 million Btu respectively.

The first item of interest is the current modification of the roof system. The insulation being installed is R-19 over either acoustical ceiling panels or gypsum wallboard. The analysis is a little difficult to determine since a single contract value of approximately $20,700 was given as the value of all the work to be performed. This value includes new lighting and ceiling fans. A rough estimate of $11,570 was determined as the value for the insulation and panels alone. The remainder would cover the lighting and miscellaneous work. The roof insulation does show an impressive $2113 savings per year. The pay back period for the insulation alone is approximately 9.7 years. This does not seem to be out of line with other values that require a large capital expense. If the lighting modification is added, the pay back period is increased to a point that a discounted pay back period cannot be calculated for the system modification.

The next area that should be closely examined is the wall areas. If the wall areas can be insulated for around $7100, the savings generated will be about $1386 per year. The pay back period for the walls would then be 8.4 years. The pay back for the walls is slightly lower than the ceilings due to the higher per square foot savings.

Ceiling fans were examined for the work bay area. The size of the bay area dictates two ceiling fans be installed to destratify the air. This requirement is based on one fan covering 2500 square feet of floor area. The calculation results in 1.3 fans for the work bay. The excess cost of the second fan pushes the pay back period out to 5.1 years. This is good considering the impact of the second fan and is close enough to the target period that the fans should be installed.

The work bay area also has a large area of windows opposite the bay doors. These windows are a source of heat loss and infiltration. The possibility of bricking or blocking in these windows and installing a lower profile window similar to those in the new unit building was examined. The simple pay back periods for both alternatives examined exceeded the target period and did not have a discounted pay back period that could be calculated. The potential measure that would work is to construct window inserts. The inserts should be insulated and fit tightly into the opening. If they are constructed properly they will save approximately the same amount of energy as the alternative examined above. The savings generated above was approximately $290 per year. Inserts could easily be constructed to result in a pay back period of less than two years.

The final area examined for the Type V building was the overhead garage doors. If new doors are installed at an approximate cost of $4400, the savings generated amount to $1040 per year. The pay back period for the new doors was calculated to be 6.2 years. This may be slightly above the target pay back range but it does represent a large annual savings.

Additional items noted during the site visit are as follows.

1. The existing water heater is an 80 gallon capacity electric water heater. Unless there is a factor not observed by the auditors this capacity exceeds the necessary amount of hot water that is needed. A smaller hot water heater should be considered for this building.

2. The steam generator has been more or less attached to the back of the building in a shed that connects to a window that has been removed. The shed did not appear to be insulated and was not sealed tightly. The opening between the steam generator and the remainder of the room it is attached to should be closed off.

3. The air conditioning system should be checked by a qualified professional to determine if either a larger central air unit is needed or if the central system should be abandoned and new window units obtained. The

most efficient would probably be the central system.

4. Like other buildings visited, there is a need to caulk windows and repair broken glass. The tendency in buildings like these is to repair glass only in areas that the general public or visitors may observe. All glass should be replaced regardless of where it is located.

5. The heating systems should be checked to determine why the capacity of the original furnace was not adequate. Adding the second furnace may or may not have been the answer to a cold spot in the office area.

Overall the Type V building does have the possibility of being a fairly energy efficient structure but only if the target pay back period limits are adjusted upward.

3.7 Common Problems, Solutions and Suggestions

There are usually a group of similar problem areas that can be addressed in a generic form. These are commonly maintenance items that can be corrected with little or no additional capital expense. The suggestions can be separated into energized, non energized and human system components. The first list is the common problems that can be corrected in the energized systems.

1. Set and lock thermostatsats at lower temperature. Locking covers for the thermostats should be

considered to minimize changes in settings.

2. All standing gas pilots should be turned off during long periods that will not require the equipment use.

3. Storage areas that do not require heat should be effectively sealed off. Thermostats in areas that do require heat should be set to the minimum allowable for the stored materials.

4. Lights should be turned off in areas not in use.

5. Regular inspections of heating and cooling equipment should be established to maximize the equipment efficiency.

6. Thermostats can be setback in the evening nonwork hours. Automatic setback thermostats can be purcased to control this function.

7. Try to establish a group replacement procedure for the lighting system and to have regular lighting maintenance.

There are also several suggestion that can be made regarding the physical or non energized systems.

1. Regularly inspect all exterior windows, doors and exterior wall penetrations (conduits, hose bibs) for caulking and weatherstripping. Repairs should be made as needed.

2. All broken glass or cracked glass should be replaced as soon as possible.

3. All areas should be reviewed and inspected for methods to reduce the infiltration air volume.

4. Gaskets for the overhead doors should be inspected and replaced as needed. New door seal systems are available to seal the upper and side edges of overhead doors.

5. Through-wall air conditioners should be covered during the heating season. Special covers can be made for these units.

Several suggestions for employees are also generic in nature.

1. Personnel should dress according to the season. Warmer clothing will reduce the temptation to change thermostat settings.

2. Often the effects of a cold floor can be reduced in office settings by simply placing a carpet remnant under the work station or desk.

3. One individual should have the responsibility to check thermostats not locked or controlled to assure that they have not been turned up.

4. Employees need to understand the importance of their role in the conservation of energy.

3.8 Comparison of Actual and Estimated Energy Use

The final objective of this study was to validate the calculated energy consumption by comparing estimated fuel consumption to data obtained on actual building consumption. Several assumptions that were made during the initial calculations need to be identified and corrected for the comparison presented here. The key assumptions made that will affect the calculations are as follows:

1. The interior design temperature for the calculations was set at 70 degrees.

2. The heating degree day value was based on an average year and for the range of buildings in the Crawfordsville District.

3. The efficiency value selected for most equipment conditions was set at 0.75.

Although there is no prima facia evidence to suggest that these values are not appropriate, they are conservative in nature and will not produce the desired results when examining a specific consumption pattern for a particular building. This does not detract from the estimated values used in the previous calculations because they are representative figures for the basis of comparison of alternatives.

The following data is more representative of the values that would apply in the analysis of the Type II building for 1982.

1. Heating degree days for 1982 were 6170 for the actual location of the Type II building audited for this study.

2. The interior thermostat temperatures observed during the initial field investigation were typically around 72 degrees F.

3. Typical efficiency values for the unit heaters observed are generally closer to 0.65.

Applying these revised figures to the calculations will result in a revised peak heating value of 103,100 Btu per hour for the Type II building. The Modified Degree Day formula for fuel consumption yields 4,256 gallons of propane. The actual consumption of the Type II building in 1982 was 4,657 gallons. The prediction is 91 percent of the actual, which is sufficiently accurate for the purposes of this study. Similar comparisons can be made for the remaining structures. Fluctuations in the results should be expected since actual conditions are not known and there may be other elements affecting the consumption pattern during a specific period. The best procedure to use would be to adjust the calculations by obtaining actual efficiencies, interior temperatures and heating degree days and modify the computations accordingly.

The total energy consumption, for the Type II Building audited, was obtained from the 1982 supplier billings. The data for all five buildings examined was obtained and compiled by entering the data in the Energy Management Form discussed in Chapter 2. The billing data provided for the Type I Building was incomplete and is not provided with the other four buildings in Appendix E.

Table 3.7 is the summary of the actual billing costs and the estimated savings generated by modifications that were proposed earlier in this section. The alternatives included in this table are provided in Tables 3.8 through 3.12 for review. One column of particular note is the far right column where the estimated percentage savings is presented. The basis for these values is the estimated savings divided by the 1982 billing costs. A similar computation should be performed on the fuel savings and then extended to dollars but the data presented provides enough proof that there is a substaintial amount of energy that can be saved.

The last estimate that can be made from the study data is the extension of the projected costs and savings for all similar buildings within a category. Table 3.13 shows this extension including the summation of all costs and savings for the five typical structures examined in this study. The

Table 3.7 Percentage Savings Summary

BUILDING TYPE	ELECTRICITY BILLINGS 1982 (a)	FUEL BILLINGS 1982 (a)	TOTAL BILLINGS 1982	ESTIMATED ANNUAL SAVINGS	ESTIMATED PERCENTAGE SAVINGS OF 1982 BILLINGS
TYPE I(b)	X	X	X	X	X
TYPE II	$495.12	$3631.12	$4126.24	$1609.00	39%
TYPE III	$1766.64	$3884.49	$5151.13	$1924.00	37%
TYPE IV	$8484.44(c)	$8860.16	$17344.60	$2065.00	12%
TYPE V	$4611.11	$7035.96	$11,647.07	$3566.00	31%

(a) The 1982 billings were complete at time of study.

(b) Insufficient billing data for Type I comparison.

(c) Electric billing reflects sign shop equipment usage.

Table 3.8 Building Type I Alternatives

ALTERNATIVE SELECTED	ESTIMATED INITIAL COST	ESTIMATED ANNUAL ENERGY SAVINGS
1.Natural Gas Furnace (a)	$1900.00	$681.00
2.Install Ceiling Fans	278.00	110.00
3.Energy Efficient Lamps	114.00	111.00
4.Install Timer on Security Lights	100.00	111.00
TOTALS	$2392.00	$1013.00

(a) Natural gas will not be available at all locations.

Table 3.9 Building Type II Alternatives

ALTERNATIVE SELECTED	ESTIMATED INITIAL COST	ESTIMATED ANNUAL ENERGY SAVINGS
1.Install New Ceiling	$3240.00	$812.00
2.Wall Insulation	2068.00	305.00
3.Install Ceiling Fans	278.00	137.00
4.New Overhead Doors	2854.00	725.00
5.New Lighting	1270.00	(a)(250.00)
TOTALS	$9710.00	$1609.00

(a) Increase over current annual cost.

Table 3.10 Building Type III Alternatives

ALTERNATIVE SELECTED	ESTIMATED INITIAL COST	ESTIMATED ANNUAL ENERGY SAVINGS
1.Reinsulate	$7150.00	$980.00
2.New Overhead Door	1430.00	280.00
3.Energy Efficient Lamps	728.00	242.00
4.Install Timer on Security Lights	200.00	256.00
5.Install Ceiling Fans	525.00	166.00
TOTALS	$10,033.00	$1924.00

Table 3.11 Building Type IV Alternatives

ALTERNATIVE SELECTED	ESTIMATED INITIAL COST	ESTIMATED ANNUAL ENERGY SAVINGS
1.Insulate Ceiling	$7250.00	1637.00
2.Energy Efficient Lamps	156.00	49.00
3.Install Ceiling Fans	370.00	379.00
TOTALS	$7776.00	$2065.00

Table 3.12 Building Type V Alternatives

ALTERNATIVE SELECTED	ESTIMATED INITIAL COST	ESTIMATED ANNUAL ENERGY SAVINGS
1.Insulation	$11,570.00	$2113.00
2.Install Ceiling Fans	370.00	120.00
3.Remove Windows	2849.00	291.00
4.New Overhead Doors	4400.00	1042.00
TOTALS	$19,189.00	$3566.00

Table 3.13 Total Savings Summary

BUILDING TYPE	TOTAL STRUCTURES	INITIAL COST	ANNUAL SAVINGS	TOTAL INITIAL COST	TOTAL ANNUAL SAVINGS
Type I	19	$2,392	$1,013	$45,448	$19,247
Type II	53	$9,710	$1,609	$514,630	$85,277
Type III	14	$10,033	$1,924	$140,462	$26,936
Type IV	11	$7,776	$2,065	$85,536	$22,715
Type V	30	$19,189	$3,566	$575,670	$106,980
GRAND TOTAL				$1,361,746	$261,155

information shown in this table should be examined with the understanding that the conditions assumed in the study will vary substaintially from one building to the next and the resulting savings and costs will vary proportionally.

Another method to look at the data in Table 3.13 would be to examine the rate of return that the savings will provide. Without spending additional time presenting present value equations, the goal of the calculation is to determine the effective interest rate that would have to be used to yield the present value of the investment. The single factor not shown that is required for the calculation is the time period over which the expected savings are expected. The longer the period of return assumed the higher the rate of return will be. The period that should be used in the calculation is the expected remaining useful life of the structure. Most of the proposed revisions are expected to be permanent with the exception of the fans that will need periodic replacement. If the expected remaining life averages 10 years, the rate of return for the investment is approximately 14 percent and if the average service life is 15 years the expected rate of return is around 17 percent. These values also provide some evidence to the effectiveness of the proposed alternatives.

In summary, there are many additional factors that can be examined in all the buildings examined in the study but the primary objectives of this investigation have been

sucessfully accomplished. The conclusions are that the potential amount of energy that can be conserved warrants continued examination, that a formal program should be established for the purpose of examining all the IDOH buildings in the State and appropriate modifications should be made to the structures as funds become available.

CHAPTER 4 RECOMMENDATIONS

4.1 Introduction

The primary goal of this study was to investigate the potential for energy conservation in existing Indiana Department of Highway maintenance buildings and to recommend changes that would have short payback periods based on energy cost savings. The data and evaluations made in this study clearly indicate that there does indeed exist a great potential for saving energy and reducing costs. It is, therefore, the purpose of this chapter to present a series of recommendations that reflect the information discovered in the study as well as present a series of recommendations that will aid in the implementation of uniform program for energy conservation.

4.2 Energy Management Program Recommendations

The primary recommendation is that there should be an energy management program established. The overall potential cost savings should provide enough incentive to IDOH officials to start an energy management program. The level of detail and depth of the program is properly an internal decision for the IDOH. However, a concerted effort by

everyone to achieve the maximum results from the program will be necessary. In order to clarify some of the major areas that are important to the program the following list presents several topics that will be discussed in the remainder of this section.

1. The objectives and purpose of the program should be clearly defined from the start and a definite system established that will ensure that all efforts are directed in the proper directions.

2. Adequate training and education of personnel responsible for the program should recieve a high priority in the development stage of the program.

3. The program will need to be capable of addressing new analysis techniques and new methods of conservation in a timely manner. This includes the ability to properly evaluate proposals and their related costs and benefits.

4. The final area that should be in the program is the review of operations and maintenance procedures within the various buildings. The purpose of the review will be to suggest changes that are directed toward energy conservation through daily maintenance routines.

The following paragraphs will highlight some of the areas

the researcher feels will need specific attention within the topics identified above. These recommendations are not intended to be all inclusive of the possible areasthat should be examined but only the highlights of areas of primary concern.

Initial Program Development

The stage that is the keystone to this or any other program is the definition and development stage. Clearly defining the purposes of the program will provide a common ground for all future work proposed under the program. The formal definition of the program will give the problem an identity and aid in the direction and coordination of the various groups and individuals involved in the program.

Two types of goals can be developed to govern both the short term and long term planning in the program. Short term goals would include the phased development of the energy management program and the determination of manpower and budgeting requirements. The short term goals should include the measureable goals of projected energy savings, as discussed in Chapter 2, in a time frame that is appropriate for the program that is established. Long term goals of the program include the expansion of the system to include additional buildings not currently in the maintenance category and possibly other areas such as vehicle fleet management.

This initial development stage is also the time that the various levels of responsibilities need to be established. Two possibilities for distributing responsibilities are immediately available within the current framework of the IDOH management system. Three distinct responsibility levels already exist that could serve as a basis for the program. The three levels that could be considered are the management, district and individual building levels. Some of the responsibilities may overlap somewhat at the district and building level. A separate system for energy management could also be established that gives statewide responsibilities to a team or teams of auditors. Each of these methods has their advantages and disadvantages. The three-tier system complicates the coordination and communication processes but has the advantages of involving personnel that are very familiar with individual building requirements. The separate energy management group will have fewer problems with communications but may be slower developing recommendations due to their lack of specific knowledge about the operating and physical characteristics of the buildings being investigated.

The final comment, in the area of establishing the basic program, relates to sources of funding. The costs for the program will need to be identified as well as the source of funds for the program. These are questions that should be resolved prior to initiating the program. If there are

going to be restraints on the funding, the personnel that evaluate the proposals developed in the program will need to be aware of them.

Personnel Training and Education

Participation in a program such as this will require 100 percent effort in all phases of development as well as implementation. The participation aspect leads into the second recommendation regarding adequate personnel training and education for the program. Most of the necessary training can be accomplished through hands-on experience after the basic understanding of the required calculations and evaluation methods has been developed. The education of personnel responsible for the actual analysis and auditing could also be accomplished through formal classwork and informal workshop training. The development of a manual for energy auditing and evaluation would be a way to develop the capacity of doing in-house energy audits. An energy audit manual would provide a concise reference for calculations and provide a systematic method of analysis that would be uniform for all personnel regardless of the program management system.

Education and training should also filter down to personnel that are not directly involved in the energy management program. All personnel need to understand the importance of the program and what exactly will be expected of

them. This could be as simple as expressing the need for all employees to dress properly for the season. Lightweight clothing in the winter generally results in the thermostat being adjusted upward by the workers to compensate for cooler inside temperatures. Changes of certain restrictions may also benefit energy conservation. The example that probably is best suited for this comment is in regards to limitations on carpeting in some office areas. An employee that is stationary during working hours, at a desk for example, may find that a simple way of preventing cold feet is to place a piece of carpeting underneath their desk. The carpet helps insulate the feet from the floor and will reduce the cold feeling often associated with slab on grade construction. Another example that was encountered during the study was the situation where the person in charge of a particular group of buildings was well informed on energy conservation but was unable to perform group lamp replacement due to purchasing restrictions.

Evaluation of Energy Proposals

The third recommendation noted, about establishing the program, addressed the evaluation and analysis of proposals. The program should not restrict itself to simply the methods and alternatives to problems examined by this study. The encouragement of original solutions to problems is necessary, but at the same time an energy management program is not designed to become a research and development program.

This study is more on the scale of a feasibility study in that it addresses the major points of conservation and mangement, but has not examined many of the finer details of bringing a building's energy consumption down to the minimum. Examining water heaters, air conditioning systems and humidity controls are examples of additional areas that should be addressed and examined as the program develops.

The future concerns of the program involve not only the continuous need to evaluate energy consumption in existing buildings but it should also address the energy consumption of new and proposed structures. New designs for buildings should be sensitive to the many factors that effect existing buildings but are not within the control of the occupants. Examples of these areas are site orientation, selection of exterior and interior materials, availability of natural wind screens and taking any advantage possible for solar heat gains. In addition to these standard features the possiblities for partial earth shelter design and/or solar design should be investigated for the maintenance structures.

Evaluating Maintenance and Operations Practices

The final area that will be discussed regarding the establishment of an energy management program is the evaluation of the current maintenance and operations practices. A large amount of energy will be conserved by simply revising

current operating and maintenance techniques. The final section of the discussion on each of the five types of buildings examined in Chapter 3 reflected some of the operating and maintenance conditions noticed by the researchers as the building audits were performed. The time for examining many of the buildings was limited, but substantial energy losses can be attributed to observed poor maintenance of items such as overhead garage doors, windows and man doors.

4.3 Recommendations for Continued Study

The discussion to this point has centered around the objectives of this study and the recommended methods to improve the energy consumption patterns of the buildings audited in this study. The study basicly concludes that there is a substantial amount of energy that can be saved and that the best method to take advantage of all the possible savings would be through the establishment of an energy management program. However, the program itself will need additional information and continued development before it becomes a satisfactory method to handle the problem. The following suggestions for continued study represent primary areas that can speed the development of energy conservation techniques for IDOH buildings.

1. The basic analysis of individual buildings needs to continue. Several buildings were grouped for

the purposes of this study, but they are in fact individual structures and will each require a complete audit before major alterations are initiated.

2. The development of an energy audit manual will enable the IDOH to undertake audits in-house. The audit manual should be a self supporting document that can be used with a minimum of additional study by the user after indoctrination on the energy evaluation methods, used in the manual has been completed.

3. The economic payback period used as a target for this study became a problem as the building reviews in Chapter 3 indicate. The logical target period for any of the buildings could be extended to at least the remaining expected life of the structure. Some analysis will need to be done on the individual structures to determine their expected replacement schedule. The target values for a payback periods can then be related to the replacement schedule. In cases where buildings are not expected to be replaced within the next several years the appropriate payback period for examination should be extended to around ten years.

4. The same basic format used in this study should be extended to all buildings within the jurisdiction of the IDOH.

5. The economic payback analysis used in this presentation could be modified and applied to other areas such as vehicle fleet energy management.

6. The introduction of life cycle cost analysis in the design stage of proposed buildings should greatly reduce the need for future modifications and major alterations. The implementation of value engineering for examining life cycle costs and functional analysis of future designs should recieve a high priority for additional study.

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REFERENCES

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APPENDICES

Appendix A
Survey Form

PURDUE
UNIVERSITY SCHOOL OF CIVIL ENGINEERING

Subject: Highway Research on Energy Conservation in IDOH Buildings.

Dear

We have been given your name by Mr. D.W. Lucas as a contact person for the XXX district. We are performing a research study to determine if any possible energy conserving opportunities might exist in IDOH maintenance buildings and, if so, what are the economic impacts of these alternatives. We have closely examined the Crawfordsville district and have classified their buildings into five separate typical building types. We are now attempting to contact the other five districts to determine if there are any other typical type buildings or any individual problematic buildings which might exist. It is at this point in which we need your help.

We have enclosed a general description and some pictures of the five typical building types we have identified to date. We need to have you classify each of the maintenance buildings in your district into a particular building type. We feel the following format is the most useful one in doing this:

Project No.: H-110 Unit 1101

Location: Located in the northeast part of Terre Haute,
2900 Fort Harrison Road

Function: Terre Haute sub-district garage

Phone: (812) 466-4261

Building Type: Type V

Civil Engineering Building
West Lafayette, Indiana 47907

When filling in the building type please describe it either as one of the existing building types, or as a different typical building type, or as a individual one-time only building type. If you decide to classify the building as either of the last two, please give us a full description of the building, such as the ones we have already identified. Even if the building has a different number of doors or a different size, it might be classifiable as one of the five typical building types. If you feel any particular buildings are consuming an extraordinary amount of energy or have an uncomfortable working condition, such as extreme drafts, please note this, so that we may address the problem in our study. In addition, please notify us if there are any previous energy conserving measures your district has tried in the recent past.

We are looking forward to your response and we are very enthusiastic about working with you in the future. If there are any questions or suggestions you might have, please feel free to call me at (317)494-2246. We will be contacting you in the near future to discuss any energy conserving suggestions you might have.

Sincerely yours,

Milo E. Riverso
Graduate Instructor
of Research

MER/bt

Enclosure

Building Type I: New Block Design

Date of Construction: 1980.

General Description:

Frame	-	Block construction with a gabled roof. Length: 62 feet. Width: 46 feet.
Roof	-	Wood truss construction and a asphalt shingle roof.
Wall	-	12" concrete blocks filled with granular insulation.
Height	-	Peak height: 23 feet. Gutterline height: 15.3 feet.
Major Doors	-	Three overhead doors.
Use	-	Maintenance unit building.
Picture	-	One front view and one back view on the following page.

Building Type II: Small Metal Building

Date of Construction: 1970.

General Description:

Frame	-	Steel frame construction with a gabled roof. Length: 63.5 feet Width: 30.0 feet
Roof	-	Galvanized metal roofing with two inches of insulation.
Wall	-	Galvanized corrugated metal siding with two inches of insulation.
Height	-	Peak height: 19 feet Gutterline height: 14 feet
Major Doors	-	One overhead door.
Use	-	Unit storage building.
Picture	-	One front view on the following page.

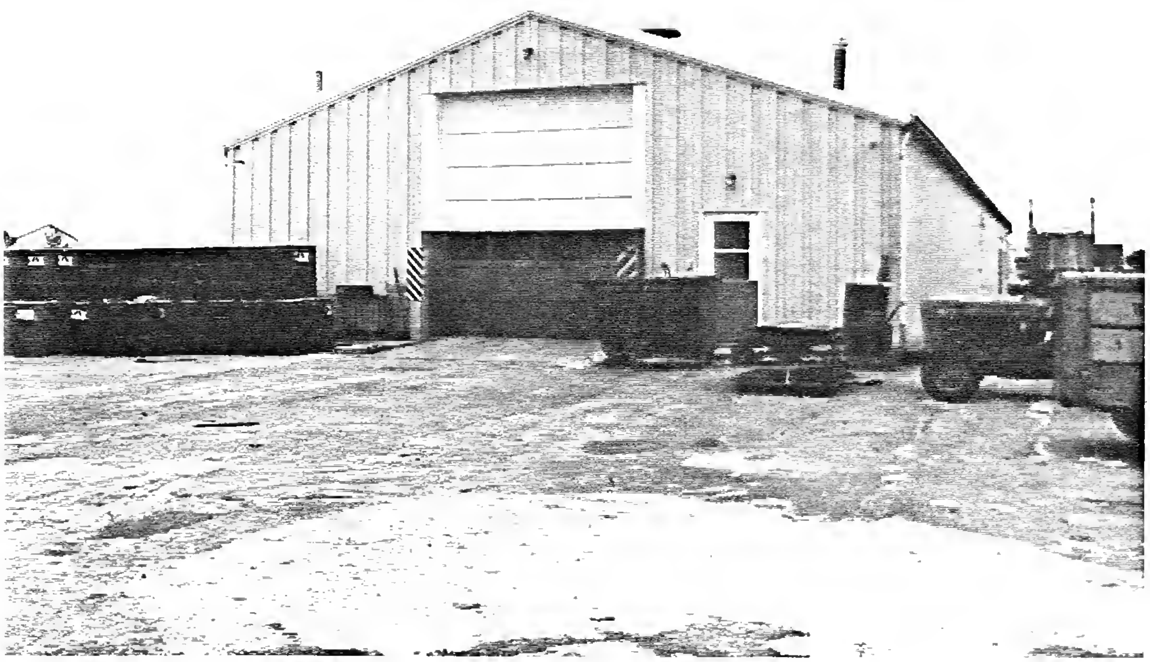

INDIANA STATE HIGHWAY COMMISSION
MAINTENANCE UNIT 1401-1402

Building Type III: Large Metal Building

Date of Construction: 1965.

General Description:

Frame	-	Steel frame construction with a gabled roof. Length: 160.5 feet Width: 40.0 feet
Roof	-	Galvanized metal roofing with two inches of insulation.
Wall	-	Galvanized metal siding with three inches of insulati
Height	-	Peak height: 18.5 feet Gutterline height: 11.9 feet
Major Doors	-	One overhead door.
Use	-	Traffic operations building.
Picture	-	One front view and one back view on the following page.

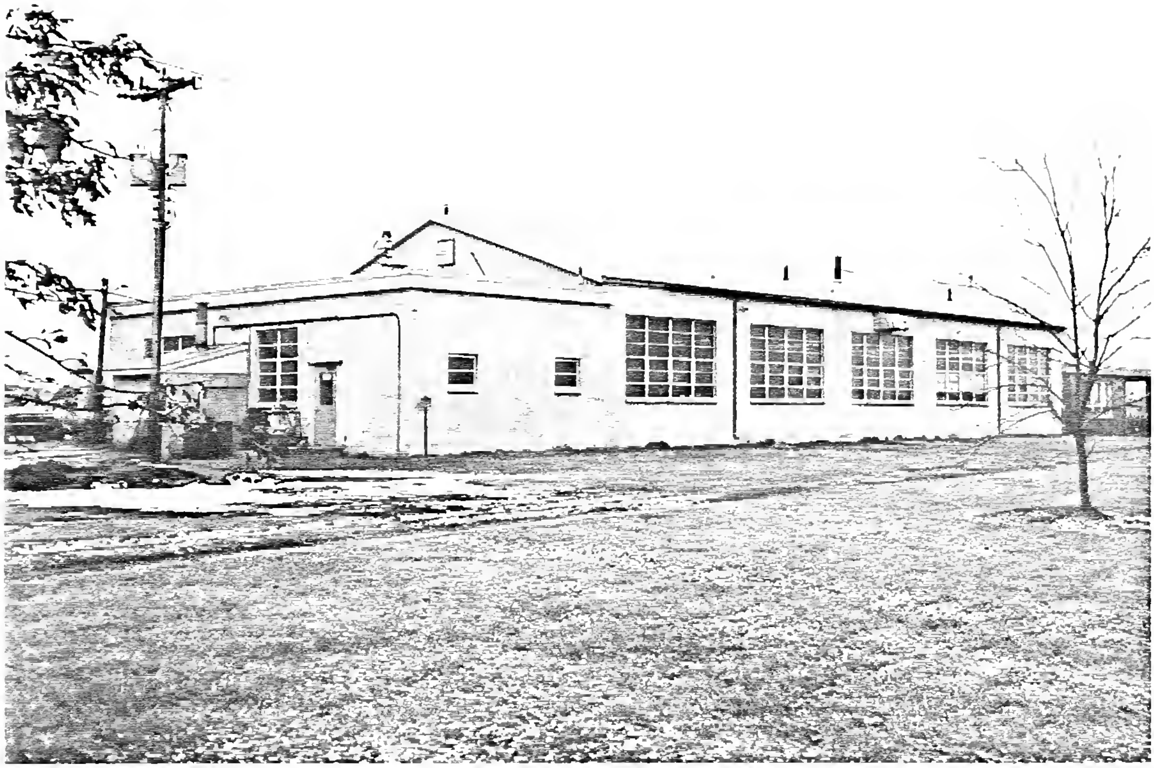


Building Type IV: Regular Block Design

Date of Construction: 1965

General Description:

Frame	-	Block wall construction Gabled roof for center section Flat roof for end sections	
		Length: 165.8 feet Width: 63 feet	
Roof	-	Center section:	Insulated metal panels
	-	Outside sections:	Concrete slab with a built-up roof.
Wall	-	East section:	8" concrete block and brick vene
	-	Center section:	12" concrete block
	-	West section	12" concrete block
	-	Attic walls:	Insulated metal siding
Height:	-	Center section:	Peak height: 24.3 feet Gutterline height: 16.7 feet
		Outside sections:	Flat roof height: 15.7 feet
Major Doors	-	Six overhead doors.	
Use	-	Office and maintenance building.	
Picture	-	One front view and one rear view on the following page.	

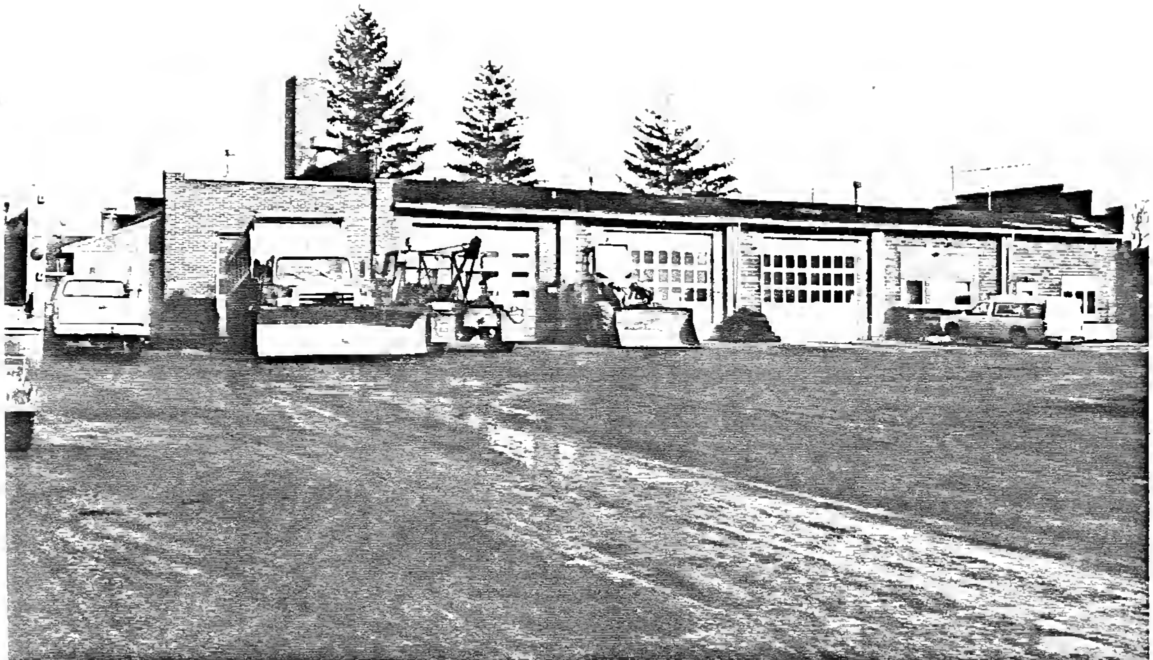


Building Type V: Arched Roof Brick Design

Date of Construction: 1929 (original construction) remodeled several times.

General Description:

Frame	-	Masonry wall construction with an arch roof. Length: 121.8 feet. Width: 52.8 feet
Roof	-	Arched steel joist construction with a built-up roof on 2x10 wood purlins.
Wall	-	Brick and concrete pilasters.
Height	-	Varies from 13 feet to 15 feet.
Major Doors	-	Four overhead doors.
Use	-	Sub-District garage.
Picture	-	One front view and one side view on the following page.

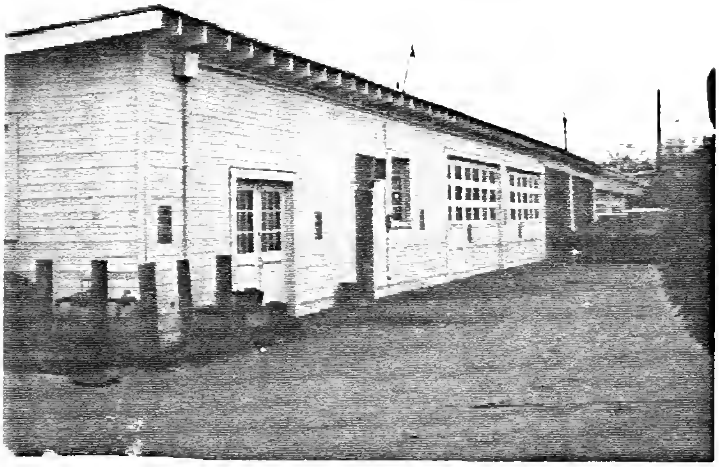


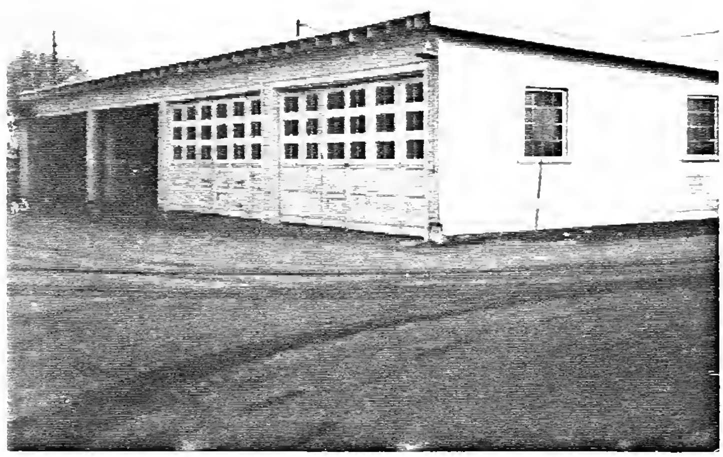
Building Type VI: Shed Type Building

Date of Construction: 1935

General Description:

Frame	-	Wooden frame construction with a flat pitched roof. Length: 30.0 feet Width: 35.0 feet
Roof	-	Roll roofing with wood truss construction.
Wall	-	Paneling (outside walls insulated).
Height	-	Peak height: 12 feet. Gutterline height: 10 feet.
Major Doors	-	3 overhead doors.
Use	-	Supply building; storage.
Picture	-	Two front views and one back view on the following page.





Appendix B
Building Information Form

BUILDING INFORMATION FORM (BIF)

I. General Description

A) General:

Name of Building ______________________________

Location ______________________________

City ______________________________ Telephone Number ______________________________

Contact Person ______________________________ Position ______________________________

Use: ______________________________ Sub-District ______________________________

District ______________________________

B) Building Type:

Metal ______________________________ New Block Design ______________________________

Brick & Block ______________________________ Arch-Roof ______________________________

Combination ______________________________

C) Operating Schedule:

	time	hours	operating temperature	Number of occupants
Day	____	____	____	____
Evening	____	____	____	____
Night	____	____	____	____
Weekends	____	____	____	____
	____	____	____	____

II. - Building Characteristics

Year of construction ______________________________.

Year(s) of Modifications ______________________________.

A) Floors

Construction (1) over heated space ______sq.ft.
over unheated space ______sq.ft.
slab on grade ______sq.ft.

(2) concrete ______sq.ft.
other (specify)________________________ ______sq.ft.

(3) Perimeter Insulation
type___________thickness____________(in)R-value__________

B) Walls

1) NORTH

a) Wall Construction

Gross Area length ______x height______ = ______ (sq.ft.)
Net Area (gross area-window and door area)

G.A.______ - W.A.______ = ______ sq.ft.

Outside Construction: Metal Frame ______sq.ft.
Concrete Block ______sq.ft.
Brick veneer ______sq.ft.
Metal wall ______sq.ft.
Other (specify)____________________ ______sq.ft.

Insulation:

type __________thickness__________(in.)R Value__________

Inside Construction: Block ______ sq.ft.
Wood ______ sq.ft.
Gypsum Board ______ sq.ft.
Metal ______ sq.ft.
Plaster ______ sq.ft.
Other (specify)___________________ ______ sq.ft.

b) Window Construction

Single Glazed ________sq.ft.

Double Glazed ________sq.ft.
(space ________ in.)

Insulating Glazed ________sq.ft.
(space ________ in.)

Other (specify) ____________________ ______sq.ft.

Shading (specify) ____________________ ______sq.ft.

Window Frame Type ______________________________

%sash/glass ______________________________%

c) Door Construction:

		No.	height	width	thickness
Wood	________	____	______	_____	________
Metal	________	____	______	_____	________
Glass	________	____	______	_____	________
Overhead	________	____	______	_____	________
Description	________				
Other(specify)	________	____	______	_____	________

2) SOUTH

a) Wall Construction

Gross Area length______x height ______ = ______(sq.ft.)

Net Area (gross area-window and door area)

G.A.______ W.A.______ = ______ sq.ft.

Outside

Construction: Metal Frame ________sq.ft.

Concrete Block ________sq.ft.

Brick veneer ________sq.ft.

Metal wall ________sq.ft.

Other (specify__________________ ________sq.ft.

Insulation:

type____________thickness_________(in.)R Value_________

Inside

Construction: Block ________sq.ft.

Wood ________sq.ft.

Gypsum Board ________sq.ft.

Metal ________sq.ft.

Plaster ________sq.ft.

Other (specify)___________________ ________sq.ft.

b) Window Construction

Single Glazed ________sq.ft.

Double Glazed ________sq.ft.
(space ________ in.)

Insulating Glazed ________sq.ft.
(space ________ in.)

Other (specify) ____________________ _______sq.ft.

Shading (specify)____________________ _______sq.ft.

Window Frame Type ______________________________

%sash/glass ______________________________

c) Door Construction:

		No.	height	width	thickness
Wood	________	____	______	_____	________
Metal	________	____	______	_____	________
Glass	________	____	______	_____	________
Overhead	________	____	______	_____	________
Description	________				
Other(specify)	________	____	______	_____	________

3) East

a) Wall Construction

Gross Area length______x height ______ = ______(sq.ft.)

Net Area (gross area-window and door area)

G.A.______ W.A.______ = ______ sq.ft.

Outside Construction:

	Metal Frame	______sq.ft.
	Concrete Block	______sq.ft.
	Brick veneer	______sq.ft.
	Metal wall	______sq.ft.
	Other (specify______________	______sq.ft.

Insulation:

type__________thickness_______(in.)R Value________

Inside Construction:

	Block	______sq.ft.
	Wood	______sq.ft.
	Gypsum Board	______sq.ft.
	Metal	______sq.ft.
	Plaster	______sq.ft.
	Other (specify)______________	______sq.ft.

b) <u>Window Construction</u>

Single Glazed ________ sq.ft.

Double Glazed ________ sq.ft.
(space ________ in.)

Insulating Glazed ________ sq.ft.
(space ________ in.)

Other (specify) ____________________ ________ sq.ft.

Shading (specify) ____________________ ________ sq.ft.

Window Frame Type ______________________________

%sash/glass ______________________________ %

c) <u>Door Construction:</u>

		No.	height	width	thickness
Wood	______	____	______	______	______
Metal	______	____	______	______	______
Glass	______	____	______	______	______
Overhead	______	____	______	______	______
Description	______				
Other(specify)	______	____	______	______	______

4) WEST

a) Wall Construction

Gross Area length______x height ______ = ______(sq.ft.)

Net Area (gross area-window and door area)

G.A.______ W.A.______ = ______ sq.ft.

Outside Construction:

Metal Frame		_______ sq.ft.
Concrete Block		_______ sq.ft.
Brick veneer		_______ sq.ft.
Metal wall		_______ sq.ft.
Other (specify	________________	_______ sq.ft.

Insulation:

type__________thickness________(in.)R Value________

Inside Construction:

Block		_______ sq.ft.
Wood		_______ sq.ft.
Gypsum Board		_______ sq.ft.
Metal		_______ sq.ft.
Plaster		_______ sq.ft.
Other (specify)	________________	_______ sq.ft.

b) Window Construction

Single Glazed ________ sq.ft.

Double Glazed ________ sq.ft.
(space ________ in.)

Insulating Glazed ________ sq.ft.
(space ________ in.)

Other (specify) ____________________ ________ sq.ft.

Shading (specify) ____________________ ________ sq.ft.

Window Frame Type ______________________________

%sash/glass ______________________________ %

c) Door Construction:

		No.	height	width	thickness
Wood	______	___	____	____	______
Metal	______	___	____	____	______
Glass	______	___	____	____	______
Overhead	______	___	____	____	______
Description	______________________________				
Other(specify)	______	___	____	____	______

C) Roof

a) Roof Construction

1) Description of Frame ______________________________

____

____.

2) Roof Angle

Flat ________sq.ft.
Pitch ________sq.ft.
Arched ________sq.ft.

3) Roofing Material:

shingles ________sq.ft.
steel ________sq.ft.
built up ________sq.ft.
Other (specify ________________________ ________sq.ft.

Color Light __________Dark __________

Condition good ________fair________poor________

4) Insulation

type ______________thickness________(in) R-Value__________

5) Inside Cover Description ____

____

____

D) Ceiling Construction

1. Attic yes________ no________
Ventilation type ____
Use ____
2. Upper covering description ____

____
3. Frame description ____

____
4. Lower covering description ____

____
5. Insulation
type ____________thickness____________(in.) R-Value____________

E) Building Measurements

1. Heated
Total Floor Area

Length ______(ft) x width _______(ft) = Area ________(sq.ft.)

2. Unheated

Total Floor Area

Length ________(ft) x width ________(ft) = Area ___________(sq.ft

3. Number of stories __________

Building height __________ (ft.)

4. Perimeter __________ (ft.)

III. MAJOR ENERGY USING SYSTEMS

Fill in the appropriate numbers for items 1 thru 5 using the numbered codes listed on the next page:

	Fuel Type(A)	Mechanical Equipment (B)	Terminal Unit(C)	Thermostat Setting-°F
1. Space Heating	______	______	______	______
2. Space Cooling	______	______	______	______
3. Hot Water	______	______	______	______
4. Kitchen	______	______	______	______

Kitchen equipment description ____

____

A. Fuel Type:

01 Coal	06 Propane
02 Electricity	07 Purchased Steam
03 No. 2 Fuel Oil	08 Wood
04 No. 6 Fuel Oil	09 Other (specify)________
05 Natural Gas	

B. Mechanical Equipment:

Heating System	Cooling System	Hot Water System
10 Low pressure steam boiler	17 Absorption	24 Hot water heater
11 High pressure steam boiler	18 Centrifugal	25 Boiler heat exchanger
12 Hot water boiler	19 Reciprocating	26 Booster/reheat
13 Forced air furnace	20 Window/wall unit	27 Solar assisted
14 Resistance	21 Heat pump	28 Other________ (specify)
15 Heat pump	22 Natural water source	
16 Other________ (specify)	23 Other________ (specify)	

C. Terminal Units

29 Radiator	33 Dual duct	37 Self-contained
30 Fan coil/radiator unit	34 Variable air volume	38 Circulating
31 Single zone	35 Induction	39 Non-Circulating
32 Multi-zone	36 Terminal reheat	40 Other________ (specify)

Nameplate Output(Btu/hr)________ ÷ Nameplate Input(Btu/hr)________ = Efficiency________

Flue Gas Analysis ________% CO_2 Combustion Efficiency ________ %

Lighting

Interior:	Area (sq.ft.)	Type (incandesc., fluoresc. etc)	Total Watts	Average Light Levels (footcandles)	Usage (hrs/wk)
Vehicle Storage & Maintenance					
General Offices					

Exterior:	Type	Total Watts	Method of Control	Usage (hrs/wk)
Parking Lot				
Building Perimeter				

6. HVAC Distribution

Fan or Pump Location, Function	Area or Zone Served	Horse Power	CFM or GPM Total	CFM Outdoor Air	Method of Control	Operating Time (Hrs/wk)

7. Electric Equipment (Data Processing, Communications, etc.
(over 300kWh/yr)

Description	Quantity	Power Rating, kW	Hours/Week

IV. AIR LEAKAGE (note quantity, location, etc.)

Cracks through walls or ceiling____________________

Loose-fitting windows____________________

Loose-fitting doors____________________

Loose-fitting air conditioners____________________

Ventilation exhaust ducts without dampers____________________

Others observed (described)____________________

V. OPENING USAGE

A) Doors Persons/Hour ________________

B) Overhead Door Number of times/day________________

Avg. time open________________(min)

c) Windows	N______	hrs/day______	Season______
	S______	______	______
	E______	______	______
	W______	______	______

VI. CLIMATIC DATA

Average Annual Heating Degree Days________________

Average Annual Cooling Degree Days________________

Main Wind Direction ________________

VII. DESCRIPTION OF ENERGY MANAGEMENT ACTIVITIES

Energy Management Team Formed Yes_____ No_____

Energy Management Coordinator Designated Yes_____ No_____

Energy Audit Completed_____ Started_____ None_____

Detailed Study by Architect or Engineer

Completed_____ Started_____ None_____

Energy Management Measures Implemented and Dates

Appendix C
Building Type I Calculations

I. HEATING LOAD CALCULATIONS - TYPE I

1.0 Location: Lafayette, Indiana

Lattitude: 40D 02M

Longitude: 86D 05M

1.1 Indoor Design Temperatures:

Winter: 70

Summer: 78 (NA)

1.2 Outdoor Design Temperatures

Winter(97.5%): 3 FDB

Summer(2.5%): 91 FDB

73 FWB

1.3 Daily Mean Range: 22 F

1.4 Attic Temperature:

assumed 5 F warmer than outside design temperature

2.0 Envelope Areas and U-values

2.1 Roof

2.1.1 Description: Gabled roof with a 1/6 pitch (4"rise,12"run) 340# asphalt shingles over 15# asphalt saturated felt over 3/4" plywood sheathing. Interior ceiling is 5/8" sheetrock attached to bottom chord of trussed with 6" batt insulation.

2.1.2 Gross Area (horizontal)

A = 62′ X 46′ = 2852 SF

2.1.3 U-value for the ceiling

MATERIALS	WINTER	
	thru wall	thru stud
Inside Surface Air	0.61	0.61
5/8" Sheet Rock	0.56	0.56
6" Batt Insulation	19.00	--
2"x6" Bott.Chord	--	7.14
Outside Surface Air	0.61	0.61
Total (R)	20.78	8.92
U-value (1/R)	0.048	0.112

for 2x6 construction on 24" centers ratio of wall to stud is approximately 90% wall 10% stud

- need to average the ceiling value by this proportion

Uave = 0.90(0.048) + 0.10(0.112)

2.2 Walls

2.2.1 Description: 12" Lightweight concrete block filled with granular insulation (perlite, vermiculite or polystyrene)

2.2.2 Area

Gross Area

A = 2(62'+46') x 15.33' = 3312 sf

Window Area

UNIT	DIMENSIONS	NO	AREA
#3616A	A = (1'-11 1/3" x 7'-1 1/2")	(1)	= 13.85 sf
#4016A	A = (1'-11 1/3" x 4'-0 1/2")	(1)	= 7.86 sf
#2816A	A = (1'-11 1/3" x 3'-0 1/2")	(2)	= 11.83 sf
#4816A	A = (1'-11 1/3" x 9'-1 1/2")	(3)	= 53.22 sf
		TOTAL	86.76 sf

Door Area

TYPE	DIMENSIONS	NO	AREA
Man Doors	A = (6'-10 3/8" x 3'-4")	(2)	= 45.76 sf
Overhead	A = (14'-0" x 14'-0")	(3)	= 588.00 sf
		TOTAL	633.76 sf

Net Opaque Wall Area

Net = Gross - Door - Window =

3312 - 633.76 - 86.76 = 2591.5 sf

Lintel Area

TYPE	DIMENSIONS	NO	AREA
Ovhd Doors	A = (16" x 14′)	(3) =	56.00 sf
L6	A = (4" x 8" x 8′-5 1/2")	(3) =	5.64 sf
L7	A = (4" x 8" x 5′-4 1/2")	(3) =	3.58 sf
L8	A = (4" x 8" x 4′-4 1/2")	(2) =	5.83 sf
L9	A = (4" x 8" x10′-5 1/2")	(3) =	20.92 sf
L2	A = (4" x 8" x 4′-8")	(2) =	6.22 sf
		TOTAL	98.19 sf

2.2.3 U-Value Wall (Opaque Area)

MATERIAL	WINTER	
	thru wall	thru stud
Inside Surface Air	0.68	0.68
12" L.W.Block w/fill	6.80	0.00
Lintels(L.W conc)	0.00	3.80
Outside Surface Air	0.17	0.17
Total (R)	7.65	4.21
U-Value (1/R)	0.131	0.238

Uave wall = 0.962(0.131) + 0.038(0.238) = 0.135 BTU/hr-sf- F

2.2.4 U-Value Windows

From Table 3.14A (ASHRAE)

No Shade

1/2" airspace assumed U = 0.49

Adjustment per Table 3.14B = 0.95

U windows = .49(.95) = 0.46

2.2.5 U-Value Doors

Overhead Doors R = 6.0 U = 1/6 = 0.167

Wood Doors 1 3/4" solid lumber core

Table 3.6 (ASHRAE) U = 0.46

3.0 Floor

3.1.1 Description : 5" thick slab on grade with 2" X 24" perimeter insulation (R = 10.0)

3.1.2 Heat Loss Per Foot of Perimeter = 30 Btu/hr-ft

Perimeter = 2(62 + 46) = 216 feet

Q(heat loss) = 216 X 30 = 6480 Btu/hr

4.0 Ventilation and Infiltration

4.1 Crack Method - applied to East Walls (most cracks)

4.1.1 Doors

Overhead Door Perimeter = 2(14 + 14) (3ea) = 168 ft

K = 3.0 (Table 5.7, ASHRAE group 158)

Gaps = 3 (9 x 14) = 378 feet

K = 1.0 (Table 5.7)

Man Door Perimeter = (6'-10 3/8" + 3'-4")2 = 20.40 ft

dp = dpw (no stack effect or pressurization)

$dpw = 0.000482\ Vw^2\ Cp$

Vw = 15 mph (ave winter velocity)

Cp = 0.95 (pressure coefficient of windward side)

dpw = (0.00482)(225)(0.95) = 0.1030275

Q = k x P x dpw   n = 0.65 for leakage openings

Q = 208.3 cfm

4.1.2 Walls

$Q = k \times A \times dp^n$

A = 339.6 square feet

Q = 17.1 cfm

4.1.3 Total Infiltration = 208.3 + 17.1 = 225.4 cfm

4.2 Ventilation : none estimated

5.0 Peak Heat Load Calculation

5.1 Ceiling : dt = 62 degrees

Q = A x U x dt = 2852 x .05044 x 62 = 9,619 btuh

5.2 Wall Opaque

Q = Aw x Uw x dt   dt = 67 degrees

Q = 2591.5 (.135)(67) = 23,440 btuh

5.3 Windows dt = 67 degrees

Q = Af x Uf x dt = 86.7(0.46)67 = 2674 btuh

5.4 Doors dt = 67 degrees

Q = Ad x Ud x dt = 45.7(0.46)(67) = 1410 btuh

5.5 Overhead Doors

Q = Aoh x Uoh x dt = 588(.167)(67) = 6579 btuh

5.6 Floor (based on perimeter losses)

Q = P x Qp = 216 x 30 btuh/ft = 6480 btuh

5.7 Infiltration

Q = 1.08 x CFM x dt = 1.08(225.4)(67) = 16,307 btuh

5.8 Peak Hourly Heat Load

AREA	HEAT LOSS
Ceiling	9,619
Walls	23,440
Windows	2,674
Doors(man)	1,410
Doors(overhead)	6,579
Floor	6,480
Infiltration	16,307
Total	66,509 btuh

6.0 Annual Energy Consumption

Heating Load

Modified Degree Day Method

Degree Days = 5500

Q(total) = Hl x D x 24 / dt

Hl = 66,509

D = 5500

dt = 67 degrees

Qt = 66509(5500)(24)/67 = 131,000,000 btu per year

7.0 U value Calculations for Code

U ceiling - no revision of previous calculation required

U walls = U wall A wall + U window A window + U doors A doors

A total

WALL AREA	U	A	UxA
Wall opaque	0.135	2591.5	349.85
Windows	0.46	86.2	39.93
Doors man	0.46	45.8	21.07
Doors overhead	0.167	522	97.2
Total Area		3312.1	
Total U x Area			509.05

U ave = 509.05/3312.1 = 0.154

II LIGHTING CALCULATIONS

1.0 General Lighting

1.1 Lumiaire Data

Keene Lighting K296 - VHO fixture

Simkar Lighting UNO - Industrial

Miller Lighting

Sylvania Lighting

Existing Fixture Style

1.2 Lamp Data

Plans: GE F96PG17/CW

Sylvania, Standard Power Groove

Fluorescent, Rapid Start 1500 ma. Cool White

F96T12/CW/VHO

2 lamps per luminaire

215 watts per lamp

2.0 Existing Lighting Level Computation

2.1 Zonal Cavity Method

2.1.1 Room Cavity Ratio (RCR) = 5(11)(0.04325) = 2.4

2.1.2 Floor Cavity Ratio (FCR) = 5(4)(.04325) = 0.90

2.1.3 Ceiling Cavity Ratio (CCR) = 5(0)(.04325) = 0

2.1.4 Effective Reflectances =

pcc = 80%

pwc = 10%

pfc = 9%

2.1.5 Coefficient of Utilization

Use fixture style 25

CU = 0.63 adjusted for pfc =9%, CU = .63/1.05 = .60

2.1.6 Light Loss Factor (LLF).

Maintenance Category II, annual maintenance, dirty environment

a. Luminaire Ambient Temperature	1.0
b. Voltage	1.0
c. Ballast Factor	1.0
d. Luminaire Surface Depreciation	0.9
e. Room Surface Depreciation	0.83
f. Room Surface Dirt	0.85
g. Lamp Lumen Depreciation	0.95
h. Luminaire Dirt Depreciation	0.86

LLF = a x b x c x d x e x f x g x h

LLF = 0.51

2.1.7 Number of Luminaires = 8

= Illuminance x Area / Lumens x CU x LLF = 37 fc/sf

this is ok for general lighting

2.2 Estimated Watts per Square foot

8 fixtures

450 watts per fixture

Area = 2143 square feet

Watts/square foot = 3600/2143 = 1.7 watts/sf

EXAMINATION OF ALTERNATIVES - BUILDING TYPE I

I. Examination of Alternate Heating Fuel Systems

$$E(\$) = \frac{Qt \times Cd \times Cf \times \$r}{V \times n}$$

Where: Qt = total annual heating load

Cd = interim correction factor for degree days

Cf = interm correction factor for fueled systems

(Cf = 1.0 for electric)

$r = fuel price per base unit

V = heating value for fuel, consistent with Hl and E($)

n = rated full load efficiency

E($) = total annual cost.

to examine systems use total annual heat loss of 131,000,000 btu/y

1.0 Electric System

V = 3413 btu/kw

$r = $0.065 /kwh

n = 1.0

Cf= 1.0

Cd = 0.734

E($) = $1,331.00

2.0 Natural Gas

V = 100,000 btu/ccf (ccf = hundred cubic feet)

$r = $0.60 /ccf

n = 0.80

Cf = 1.56

Cd = 0.734

E($) = $1,125.00

3.0 Propane

V = 91,500 Btu /gallon

$r = $0.86/gallon

n = 0.75

Cf = 1.56

Cd = .734

E($) = $1880.00

4.0 Fuel Oil #2

V = 138,000 btu/gallon

$r = $1.04 / gallon

n = 0.75

Cf = 1.68

Cd = 0.734

E($) = $1,623.00

5.0 Fuel Cost Ranking

1. Natural Gas
2. Fuel Oil #2
3. Electric
4. Propane

these were based on local costs for fuel

ESTIMATE WORK SHEET

Project Title IDOH Date 5/10/83

Project No. BLDG TYPE I Estimated by GRS Sheet 1 of

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB CONTR.	MATERIAL	LABOR	SUB CONTRACT	TOTAL
Estimated cost of heating systems									
installed cost including gas/oil									
piping to outside wall and									
minimum ductwork, includes									
installation of flue on combustion									
furnaces									
Electric Furnace									
Carrier 40ES130	1	ls			✓			$1750.00	
Natural Gas									
Carrier 58GS/GE,100	1	ls			✓			$1800.00	
Fuel Oil									
Carrier 58HV100	1	ls			✓			$2550.00	
[illegible]									
Carrier 58GS100	1	ls			✓			$1800.00	

ACCOUNT NO

Wiley-Fisk Form 11 5

POTENTIAL ENERGY CONSERVATION OPPORTUNITIES
LIFE CYCLE COST ANALYSIS FORM

Item TYPE I BLDG. HEATING SYSTEM Date 5/10/83

Description CURRENT SYSTEM - ELECTRICAL HEAT
ALT Nº1 - NATURAL GAS
ALT Nº2 - PROPANE GAS

	Label	Item	Current System	Alternative No. 1	Alternative No. 2
Input Data	IC	Initial Costs ($)	$ 1950 –	$ 1900 –	$ 1900 –
	FC	Fuel Consumption (units/yr)	28,169 kwh	1875 CCF	2186 gal
	FP	Projected Average Fuel Price ($/unit)	$ 0.065/kwh	$ 0.60/CCF	$ 0.86/gal
	AOC	Annual Operating Costs ($/yr.)	$ 25	$ 50	$ 50
	EL	Estimated Life Time (yr.)	20	20	20
Calculations	AFC	Annual Fuel Costs = FC x FP ($/yr.)	$ 1831 –	$ 1125 –	$ 1880 –
	AFS	Annual Fuel Savings = AFC_C-AFC_A ($/yr.)	—	$ 706	N/A
	AC	Annual Costs = AFC+AOC ($/yr.)	$ 1856 –	$ 1175 –	$ 1930 –
	ACS	Annual Cost Saving = AC_C-AC_A ($/yr.)		$ 681 –	N/A
	SPP	Simple Payback Period = IC/ACS (yr.)		2.8	—
	PP	Payback Period* = n (IC=ACS (P/A, n, i%)) (yr.)		3.4	—

* Assume an interest rate i = 12%
(P/A, n, i%) = Present Worth Factor

POTENTIAL ENERGY CONSERVATION OPPORTUNITIES
LIFE CYCLE COST ANALYSIS FORM

Item TYPE I HEATING SYS CON'T Date 5/10/83

Description ALT Nº 3 - OIL HEAT SYSTEM

Label	Item	Current System	Alternative No. 1	Alternative No. 2
IC	Initial Costs ($)	$2550		
FC	Fuel Consumption (units/yr)	1569 gal		
FP	Projected Average Fuel Price ($/unit)	$1.04/gal		
AOC	Annual Operating Costs ($/yr.)	$ 75		
EL	Estimated Life Time (yr.)	20		
AFC	Annual Fuel Costs = FL x FP ($/yr.)	$1632		
AFS	Annual Fuel Savings = AFC_C-AFC_A ($/yr.)	$199		
AC	Annual Costs = AFC+AOC ($/yr.)	$1707		
ACS	Annual Cost Saving = AC_C-AC_A ($/yr.)	$ 149-		
SPP	Simple Payback Period = IC/ACS (yr.)	17.1		
PP	Payback Period* = n (IC=ACS (P/A, n, i%)) (yr.)	—		

Rows IC through EL: Input Data. Rows AFC through PP: Calculations.

* Assume an interest rate i = 12%
(P/A, n, i%) = Present Worth Factor

II Ceiling Fans

Calculations based on Emerson Ceiling Fan Brochure #BL/HF - 1208 adjusted for cost savings to permit application of modified degree day formula.

1.Building Parameters - include only area where fan air will distribute.

a. Length 62 feet

b. Width 46 feet

c. Height 15.3 feet

d. Roof Pitch flat (not accounting for roof because of ceiling)

	Overhead	Mandoor
e.Doors Height (above 5′)	9.0	2.0
f.Door Width	14	3

g.Uninsulated

h.Window Height 1.75

i.Window Length 3 @ 8.83 feet

j.Wall Construction: Concrete Block

k.Wall insulated

2.Roof - 62′ x 46′ x 1 = 2852 square feet

3.Walls - (15.3)((46+62)2) - (8.66-5)(46+9(2)) = 1991 square feet

4.Doors - 9 x 3(14) + 2(3) = 384 square feet

5.Windows - 3(1.75 x 8.83) = 46 square feet

6.Effective Wall Area - 1991 - 384 -46 = 1561 square feet

7.Infiltration - (62 x 46 x 15.3)-(8.66 x 46 x 9) =

ESTIMATE WORK SHEET

Project Title ~~IDOL Study~~ Date [illegible]

Project No. Bldg Type 1 Estimated by [illegible] Sheet ____ of ____

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB CONTR	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
Emerson HF-332									$
Ceiling Fan	1	21				$[illegible]0			[illegible]
Emerson [illegible] Switch	1	21				18			18
[illegible]	1	25				50	50		100
TOTAL									$[illegible]
ACCOUNT NO									

Wiley-Fisk Form 11 5

POTENTIAL ENERGY CONSERVATION OPPORTUNITIES

LIFE CYCLE COST ANALYSIS FORM

Item Ceiling Fans Date 5/20/83

Description (Current - Electrical Heating)

Mutually Exclusive Comparison
- Alt. No 1 - Natural Gas
- Alt No 2 - Propane
- Alt No 3 - Fuel Oil

Based on Emerson HF352 HRS L-356-5 FS56"

	Label	Item	Current System	Alternative No. 1	Alternative No. 2
Input Data	IC	Initial Costs ($)	$278	$278	$278
	FC	Fuel Consumption (units/yr)	410 kwh	410 kwh	410 kwh
	FP	Projected Average Fuel Price ($/unit)	$ 0.065	$ 0.065	$ 0.065
	AOC	Annual Operating Costs ($/yr.)	—	—	—
	EL	Estimated Life Time (yr.)	5	5	5
Calculations	AFC	Annual Fuel Costs = FC x FP ($/yr.)	$ 27	$27	$ 27
	AFS	Annual Fuel Savings = ~~$AFC_C - AFC_A$~~ ($/yr.) FROM CALCULATIONS	$209	$ 137	$ 217
	AC	Annual Costs = AFC+AOC ($/yr.)	$ 27	$ 27	$ 27
	ACS	Annual Cost Saving = ~~$AC_C - AC_A$~~ ($/yr.) N/A	$ 182	$ 110	$ 190
	SPP	Simple Payback Period = IC/ACS (yr.)	1.5	2.5	1.5
	PP	Payback Period* = n(yr) (IC=ACS (P/A, n, i%)) (yr.)	1.8	3.2	1.7

* Assume an interest rate i = 12%
(P/A, n, i%) = Present Worth Factor

POTENTIAL ENERGY CONSERVATION OPPORTUNITIES
LIFE CYCLE COST ANALYSIS FORM

Item Ceiling Fans Continued Date 5/20/'83

Description

Label	Item	~~Current System~~ ALT No 3	Alternative No. 4	Alternative No. 5
IC	Initial Costs ($)	$ 278		
FC	Fuel Consumption (units/yr)	410 kwh		
FP	Projected Average Fuel Price ($/unit)	0065		
AOC	Annual Operating Costs ($/yr.)	—		
EL	Estimated Life Time (yr.)	5		
AFC	Annual Fuel Costs = FC x FP ($/yr.)	$ 27		
AFS	Annual Fuel Savings = ~~$AFC_C - AFC_A$~~ ($/yr.) FROM CALCULATIONS	$ 186		
AC	Annual Costs = AFC+AOC ($/yr.)	$ 27		
ACS	Annual Cost Saving = ~~$AC_C - AC_A$~~ ($/yr.)	$ 159		
SPP	Simple Payback Period = IC/ACS (yr.)	1.7		
PP	Payback Period* = n (IC=ACS (P/A, n, i%)) (yr.)	2.1		

* Assume an interest rate i = 12%
(P/A, n, i%) = Present Worth Factor

40,050 square feet

8.Heat Loss (Based on Emerson Charts and Tables)

a)Roof 160 Btuh/dF

b)Walls 193

c)Doors 426

d)Windows 27

e)Infiltration 35

f)Total 841

9.Temperature Difference (15-3)=12 feet

assume 3/4 degree rise per foot of height above 3 feet

12'(3/4) = 9 degrees

10. Heat Savings per Hour

841 x 99 = 7569 Btu/Hr

11. Heat Savings/ Heating Season

Btu Savings/Year = based on 5500 Heating Degree Days

Btu/yr = (7569)(24)(5500)/67 = 15,000,000 Btu

12.Cost Savings (Modified Degree Day Method)

Electric Heating System = $209.00

Natural Gas Heating System = $137.00

#2 Fuel Oil Heating = $186.00

Propane Heating = $217.00

13.Energy Consumption of Fan

Fan- 114 watts

Heating Season - 150 days

Fan runs 24 hours per day during heating system

Energy Cost = $0.065/kwh

Cost of Fan Operation = $27.00 per Year.

IV. Lighting

1.Operating Conditions - 7:30am-4:00pm

8.5hrs/day x 5 days/week = 42.5 hrs/week

52weeks per year = 2210 hrs per year

Snow conditions (assume 25 nights)

25 x 15.5 =387.5 hrs

Fluorescent Lighting Operation = 2210 + 387 = 2597 hrs/yr

Floodlights- manual switch turn on at 4:00pm

15.5hrs/day x 5 days/wk x 52 wks/yr = 4030 hrs/yr

weekends 52 x 48 = 2496

Total Floodlight Operation = 6526 hours/year

2.Lighting Operation Costs (estimated)

Annual Maintenance

	labor	material	equipment
Washing Fixture	1.92	0.10	0.03
Relamp	0.38	1.28	---
Repair Fixture	0.10	0.10	---
	-----	------	-----
	2.40	1.48	0.03
	1.48		
	.03		

3.91 x 8 = $31.28/year

POTENTIAL ENERGY CONSERVATION OPPORTUNITIES

LIFE CYCLE COST ANALYSIS FORM

Item LAMP REPLACEMENT Date 5/25/23

Description CURRENT SYSTEM - GE F96 PG17/CW

ALTERNATE #1 RELAMP WITH F96PG17/LW/WM

	Label	Item	Current System	Alternative No. 1	Alternative No. 2
Input Data	IC	Initial Costs ($)	$82.96	$113.76	
	FC	Fuel Consumption (units/yr)	9612kwh	7903kwh	
	FP	Projected Average Fuel Price ($/unit)	0.065	0.065	
	AOC	Annual Operating Costs ($/yr.)	—	—	
	EL	Estimated Life Time (yr.)	5.6⇒6	5.6⇒6	
Calculations	AFC	Annual Fuel Costs = FC x FP ($/yr.)	$624.8	$513.7	
	AFS	Annual Fuel Savings = AFC_C-AFC_A ($/yr.)	—	$111.1	
	AC	Annual Costs = AFC+AOC ($/yr.)	$624.8	$513.7	
	ACS	Annual Cost Saving = AC_C-AC_A ($/yr.)	—	$111.1	
	SPP	Simple Payback Period = IC/ACS (yr.)	—	1.0	
	PP	Payback Period* = n (yr) (IC=ACS (P/A, n, i%)) (yr)	—	1.2	

* Assume an interest rate i = 12%
(P/A, n, i%) = Present Worth Factor

POTENTIAL ENERGY CONSERVATION OPPORTUNITIES
LIFE CYCLE COST ANALYSIS FORM

Item LIGHTING SYSTEM Date 5-25-83

Description "CURRENT SYSTEM" Includes Fixtures Lamps wiring and Installation (F96PGIT/CW/VHO) 1500ma

ALTERNATE No 1 - 430mA (F96T12/CW/WM) w/ MARK II E2.95

ALTERNATE No 2 - 18 FIXTURES 400w Sodium lamp w/ Prismatic Lens HID

	Label	Item	Current System	Alternative No. 1	Alternative No. 2
Input Data	IC	Initial Costs ($)	$1763.00	$2166.00	$1800
	FC	Fuel Consumption (units/yr)	9612 kwr	6007.5 kwr	5180
	FP	Projected Average Fuel Price ($/unit)	$0.065	$0.065	$0.065
	AOC	Annual Operating Costs ($/yr.)	$31.50	$70.40	$20.00
	EL	Estimated Life Time (yr.)	20	20	20
Calculations	AFC	Annual Fuel Costs = FC x FP ($/yr.)	$624.80	$390.5	$336.7
	AFS	Annual Fuel Savings = AFC_C-AFC_A ($/yr.)	—	$234.3	$2[illegible].1
	AC	Annual Costs = AFC+AOC ($/yr.)	$656.3	$460.5	$356.7
	ACS	Annual Cost Saving = AC_C-AC_A ($/yr.)	—	$195.80	$299.6
	SPP	Simple Payback Period = IC/ACS (yr.)	—	11.1	6.0
	PP	Payback Period* = n (IC=ACS (P/A, n, i%)) (yr.)	—		11.3

* Assume an interest rate i = 12%
(P/A, n, i%) = Present Worth Factor

** ALL COSTS BASED ON NATIONAL AVERAGE COSTS

3.Substitution of Alternate No 1 for Existing System

Initial Cost of Current System $1763.00

Initial Cost of Alternate Syatem $2166.00

Increased Cost New System $403.00

Annual Cost Savings over existing $195.8

Simple Payback = 403/195.8 = 2.1 years

Discounted Payback Period = 2.5 years

4.Substiution of Alternate 2

Initial Cost Alt 2 = $1800.00

Increased Cost of New System = 37.00

Annual Cost Savings = $299.6

Simple Payback 1.5 months

Discounted Payback = --

5. Floodlights

current operation 6526 hours per year

Assume photocells reduce operation to approx 10 hours per day

Operating time saved 2850 hours

2 fixtures with 2 lamps each @ 150 watts per lamp

Energy Savings = (2 x 2 x 150 /1000)(2850) = 1710 kwh

Cost Savings = 1710 kwh x $0.065/kwh = $111.15

Estimated cost of photocells installed = $100.00

Simple Payback Period = 100//111.15 = 0.9 year

Appendix D
Sample Energy Management Forms

FORM 12 HISTORICAL QUANTITY AND COST DATA FOR ELECTRICITY

BUILDING ______________

METER SERIAL NO. ______________

LOCATION ______________

UTILITY ______________

RATE SCHEDULE ______________

BILLING PERIOD (1)	MAXIMUM DEMAND KW (2)	POWER FACTOR (3)	CONSUMPTION KWH (4)	TOTAL COST $ (5)	COST $/KWH (6)	CONSUMPTION MILLION BTU (7)	COST $/MILLION BTU (8)
ANNUAL							

FORM 13 HISTORICAL QUANTITY AND COST DATA FOR NATURAL GAS

BUILDING ____________________ UTILITY ____________________

METER SERIAL NO. ____________________ RATE SCHEDULE ____________________

LOCATION ____________________

BILLING PERIOD (1)	MAXIMUM DEMAND (2)	CONSUMPTION ☐ CCF ☐ THERMS (3)	HHV (4)	TOTAL COST $ (5)	$ COST PER ☐ CCF ☐ THERMS (6)	CONSUMPTION MILLION BTUS (7)	COST $/MILLION BTU (8)
ANNUAL							

FORM 14 HISTORICAL QUANTITY AND COST DATA FOR FUEL OIL

BUILDING ____________

SUPPLIER ____________

STORAGE CAPACITY ____________ GALS.

FUEL OIL GRADES: (USE SEPARATE FORM FOR EACH GRADE)

- ☐ NO. 2 FUEL OIL 0.139 Million Btu/gallon
- ☐ NO. 4 FUEL OIL 0.150 Million Btu/gallon
- ☐ NO. 5 FUEL OIL 0.152 Million Btu/gallon
- ☐ NO. 6 FUEL OIL 0.153 Million Btu/gallon

MONTH (1)	INVENTORY, GALLONS (2)	DELIVERIES, GALLONS (3)	CONSUMPTION, GALLONS (4)	COST, $/GALLON (5)	TOTAL COST, $ (6)	CONSUMPTION, MILLION BTU (7)	COST $/MILLION BTU (8)
END OF MONTH							
ANNUAL							

FORM 15 HISTORICAL QUANTITY AND COST DATA FOR PROPANE

BUILDING ______________ SUPPLIER ______________

METER SERIAL NO. ______________ STORAGE CAPACITY ______________ GALS

LOCATION ______________

MONTH (1)	INVENTORY, GALLONS (2)	DELIVERIES, GALLONS (3)	CONSUMPTION, GALLONS (4)	COST, $/GALLON (5)	TOTAL COST, $ (6)	CONSUMPTION, MILLION BTU (7)	COST $/MILLION BTU (8)
END OF MONTH							
ANNUAL							

Appendix E
Billing Data

BUILDING TYPE II

1982 Year

Month	Heating Deg. Days	Cooling Deg. Days	Electricity: kWh	Electricity: kWh/ Deg. Days	Electricity: kW Demand Actual	Electricity: kW Demand Billed	Electricity: Cost Total	Electricity: Cost Per Ut.	Purchased Steam: M (lbs.)	Purchased Steam: M (lbs.)/ Deg. Days	Purchased Steam: lbs/hr Demand Actual	Purchased Steam: Demand Billed	Purchased Steam: Cost Total	Purchased Steam: Cost Per Unit	Fuel: Oil Quant. (Gal.)	Fuel: Oil Cost Total	Fuel: Oil Cost Per Unit	Fuel: Check Gas ☑ Coal ☐ Other ☐ Quant.	Fuel: Cost Total	Fuel: Cost Per Unit	Fuel/ Deg. Days	Total Energy Cost
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	$ 20	21	22	23
Jan.						2110	114.00											1450	1140.15			
Feb.						2600	136.71											1127.1	853.22			
March						980	60.80											850	634.95			
1st Quarter																						
April						610	40.81															
May						160	12.33															
June						210	15.69															
2nd Quarter																						
July						110	8.83															
Aug.						130	10.33															
Sept.						140	10.86											400	310.80			
3rd Quarter																						
Oct.						280	20.28															
Nov.						300	21.90															
Dec.						640	42.58											830.1	728.00			
4th Quarter																						
Total Per Year						8270	$ 495.12											4857.2	$ 3631.12			

Building Data

Gross Conditioned Area (ft)^2 ____________

Gen. Notes: TAKEN FROM ACTUAL BILLING DATA 1982

Annual Energy Consumption in Btu

	Quantity			Conversion Fac.		Btu/Yr
1.	____ Electricity	kWh	X	3413	=	____
2	____ Purchased Steam	(M) lbs	X	1,000,000	=	____
3.	____ Natural Gas	MCF	X	1,030,000	=	____
4	____ Oil	Gallons	X	#2- 138,700 #6- 149,700	=	____
5	____ Other Fuel		X	____	=	____
				6 Total		____

Energy Utilization Index

$$EUI = \frac{\text{Total Energy Consumption Btu/yr}}{\text{Gross Conditioned Area (ft)}^2}$$

= ____________ Btu/ft^2/Yr

TYPE III

1982 Year

Month	Heating Deg. Days	Cooling Deg. Days	Electricity: kWh	Electricity: kWh/Deg. Days	Electricity: kW Demand Actual	Electricity: kW Demand Billed	Electricity: Cost Total	Electricity: Cost Per Ut.	Purchased Steam: M (lbs.)	Purchased Steam: M (lbs.)/Deg. Days	Purchased Steam: lbs/hr Actual	Purchased Steam: Demand Billed	Purchased Steam: Cost Total	Purchased Steam: Cost Per Unit	Oil: Quant. (Gal.)	Oil: Cost Total	Oil: Cost Per Unit	Fuel NAT. GAS (Check Gas ☐ Coal ☐ Other ☒): Quant.	Fuel: Cost Total	Fuel: Cost Per Unit	Fuel/Deg. Days	Total Energy Cost
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Jan.						69	130.53											2001	727.26			
Feb.						71	144.09											1778	664.25			
March						60	135.93											1072	417.97			
1st Quarter																						
April						71	154.88											816	319.55			
May						57	123.88											151	60.32			
June						59	130.44											29	13.15			
2nd Quarter																						
July						70	156.47											18	8.90			
Aug.						90	197.60											22	10.63			
Sept.						66	152.26											130	59.13			
3rd Quarter																						
Oct.						61	135.07											205	103.40			
Nov.						72	167.11											735	400.98			
Dec.						61	138.38											1084	598.95			
4th Quarter																						
Total Per Year						807	1766.64											8041	3384.49			

Building Data

Gross Conditioned Area (ft)² ______________________

Gen. Notes: ______________________

____

____

Annual Energy Consumption in Btu

Quantity			Conversion Fac.		Btu/Yr
1. ________ Electricity	kWh	x	3413	=	________
2. ________ Purchased Steam	(M) lbs	x	1,000,000.	=	________
3. ________ Natural Gas	MCF	x	1,030,000	=	________
4. ________ Oil	Gallons	x	#2 138,700 #6 149,700	=	________
5. ________ Other Fuel		x	________	=	________
			6 Total		________

Energy Utilization Index

$$EUI = \frac{\text{Total Energy Consumption Btu/yr}}{\text{Gross Conditioned Area (ft)}^2}$$

= ______________ Btu/ft²/Yr

TYPE IV

1982 Year

Month	Heating Deg. Days	Cooling Deg. Days	Electricity kWh	Electricity kWh/ Deg. Days	Electricity kW Demand Actual	Electricity kW Demand Billed	Electricity Cost Total	Electricity Cost Per Ut.	Purchased Steam M (lbs.)	Purchased Steam M (lbs.)/ Deg. Days	Purchased Steam lbs/hr Demand Actual	Purchased Steam Demand Billed	Purchased Steam Cost Total	Purchased Steam Cost Per Unit	Fuel NAT. GAS: Oil Quant. (Gal.)	Oil Cost Total	Oil Cost Per Unit	Check Gas ☒ Coal ☐ Other ☐ Quant.	Cost Total	Cost Per Unit	Fuel/ Deg. Days	Total Energy Cost
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Jan.							981.37											5018	1820.75			
Feb.							1076.45											5216	1944.77			
March							1006.67											2833	1101.22			
1st Quarter																						
April							904.02											2087	814.13			
May							387.89											452	176.54			
June							390.25											302	117.87			
2nd Quarter																						
July							500.00	EST.										151	58.89			
Aug.							611.86											312	124.24			
Sept.							432.22											290	129.42			
3rd Quarter																						
Oct.							435.48											710	353.06			
Nov.							788.62											1704	921.67			
Dec.							969.63											2364	1297.60			
4th Quarter																						
Total Per Year							#8484.44											21439	$8860.16			

INCLUDES SHOP SIGN TOTAL
MACHINE IN
BILLINGS

Building Data

Gross Conditioned Area (ft)² ____________

Gen. Notes: ____________

Annual Energy Consumption In Btu

Quantity			Conversion Fac.		Btu/Yr
1. ______ Electricity	kWh	X	3413	=	______
2. ______ Purchased Steam	(M) lbs	X	1,000,000.	=	______
3. ______ Natural Gas	MCF	X	1,030,000	=	______
4. ______ Oil	Gallons	X	#2- 138,700 #6- 149,700	=	______
5. ______ Other Fuel		X	______	=	______
			6 Total		______

Energy Utilization Index

$$EUI = \frac{\text{Total Energy Consumption Btu/yr}}{\text{Gross Conditioned Area (ft)}^2}$$

= ____________ Btu/ft²/Yr

TYPE V

1982 Year

Month	Heating Deg. Days	Cooling Deg. Days	Electricity kWh	Electricity kWh/Deg. Days	Electricity kW Demand Actual	Electricity kW Demand Billed	Electricity Cost Total	Electricity Cost Per Ut.	Purchased Steam M (lbs.)	Purchased Steam M (lbs.)/Deg. Days	Purchased Steam lbs/hr Demand Actual	Purchased Steam Demand Billed	Purchased Steam Cost Total	Purchased Steam Cost Per Unit	Fuel: Oil Quant. (Gal.)	Fuel: Oil Cost Total	Fuel: Oil Cost Per Unit	Fuel: Check: Gas ☒ Coal ☐ Other ☐ Quant.	Fuel: Cost Total	Fuel: Cost Per Unit	Fuel/Deg. Days	Total Energy Cost
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	22
Jan.						6005	551.95											3824	1460.4			
Feb.						6178	561.81											3594	1402.32			
March						5103	473.50											2491	995.71			
1st Quarter																						
April						3561	346.82											1848	745.71			
May						3202	323.55											341	146.48			
June						2952	302.05											225	100.92			
2nd Quarter																						
July						3658	363.35											136	63.17			
Aug.						3357	350.75											110	52.37			
Sept.						2289	262.39											111	56.57			
3rd Quarter																						
Oct.						2346	263.33											448	216.87			
Nov.						3242	356.06											1556	751.76			
Dec.						4329	455.55											2156	1043.67			
4th Quarter																						
Total Per Year						46222	$4611.11											16840	$7035.96			

Building Data

Gross Conditioned Area (ft)^2 __________

Gen. Notes: DOES NOT INCL. DUSK TO DAWN LIGHTING

Annual Energy Consumption in Btu

Quantity			Conversion Fac.		Btu/Yr
1. ______ Electricity	kWh	x	3412	=	______
2. ______ Purchased Steam	(M) lbs	x	1,000,000.	=	______
3. ______ Natural Gas	MCF	x	1,030,000	=	______
4. ______ Oil	Gallons	x	#2- 138,700 #6- 149,700	=	______
5. ______ Other Fuel		x	______	=	______
			6. Total		______

Energy Utilization Index

$$EUI = \frac{\text{Total Energy Consumption Btu/yr}}{\text{Gross Conditioned Area (ft)}^2}$$

= __________ Btu/ft^2/Yr

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